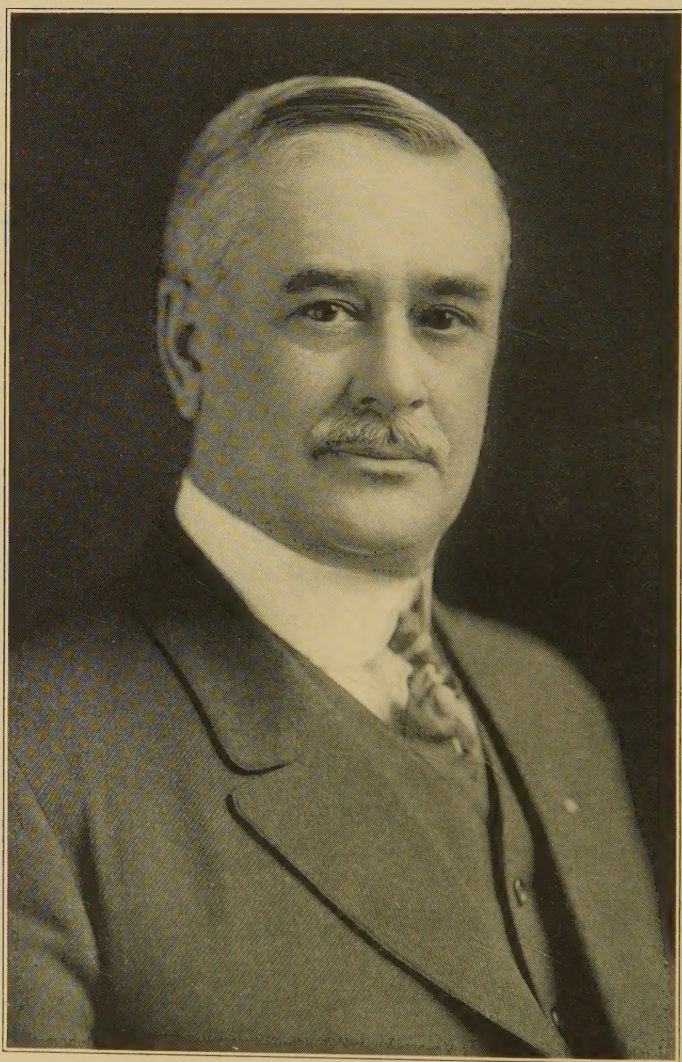




S. J. Johnston

STONINGTON

President A. M. L. ... ASSOCIATION, 1908-1909

Sam T. Johnson, twenty-eight president of the American Foundry men's Association, is a native of Scotland, having been born at Glasgow, June 2, 1860. Educated in the schools of his native city, where twenty-three years old he came to America obtaining a position in the shipping department of the Detroit Car Wheel Company, later when the Detroit Foundry Equipment Company, afterwards known as the Whiting Corporation, was organized. Mr. Johnson became connected with this organization, remaining with it for ten years. His next position was with the S. D. Conner Company of Chicago, with which organization he is now connected as vice president. Mr. Johnson is also vice president of the National Foundrymen's Company of Chicago.

Mr. Johnston has been especially prominent in the affairs of the A. R. A. since its organization. Attending the first convention in 1886 he has the distinction of having attended every subsequent convention and having been present at every Board of Directors meeting while serving as a director. A position held for many years representing the cement manufacturers. Mr. Johnston was first elected vice president for the year 1898-1899 and again in 1911, serving for two years. He has also served on many committees, rendering especially valuable service during the reorganization of the Association in 1916 when the Association was incorporated. He further distinguished himself as a very able leader in the A. R. A. group of delegates attending the Third National Portland Cement Convention held in London in 1929.

Mr. Johnson also has been closely connected with the development of the Fishery Management Association serving as its president for the years 1926 and was president of the original Foundry and Shipbuilding Association which held exhibitions at the 1900 Philadelphia and 1907 Cleveland conventions. For nine years he was a member and president of the Riverside Board of Education, president for two years of the Riverside Golf Club and a member of the Union League Club of Chicago.

S. T. Johnston

PRESIDENT, AMERICAN FOUNDRYMEN'S ASSOCIATION, 1928-1929.

Sam T. Johnston, twenty-eighth president of the American Foundrymen's Association, is a native of Scotland, having been born at Glasgow, June 2, 1866. Educated in the schools of his native city, when twenty-three years old he came to America, obtaining a position in the shipping department of the Detroit Car Wheel Company. Later when the Detroit Foundry Equipment Company, afterwards known as the Whiting Corporation, was organized, Mr. Johnston became connected with this organization, remaining with it for ten years. His next position was with the S. Obermayer Company of Chicago, with which organization he is still connected as vice president. Mr. Johnston is also vice president of the National Engineering Company of Chicago.

Mr. Johnston has been especially prominent in the affairs of the A. F. A. since its organization. Attending the first convention in 1896, he has the distinction of having attended every subsequent convention and having been present at every Board of Directors meeting while serving as a director, a position held for many years representing the equipment manufacturers. Mr. Johnston was first elected vice president for the year 1908-1909 and again in 1927, serving for two years. He has also served on many committees, rendering especially valuable service during the re-organization of the Association in 1916 when the Association was incorporated. He further distinguished himself as a very able leader of the A. F. A. group of delegates attending the Third International Foundry Congress held in London in 1929.

Mr. Johnston also has been closely connected with the development of the Foundry Equipment Manufacturers' Association, serving as its president for the year 1926, and was president of the original Foundry Supply Association, which held exhibitions at the 1906 Philadelphia and 1907 Cleveland conventions. For nine years he was a member and president of the Riverside Board of Education, president for two years of the Riverside Golf Club and a member of the Union League Club of Chicago.

TRANSACTIONS OF THE

American

Foundrymen's Association



Proceedings of the

Thirty-third Annual Meeting

CHICAGO, ILLINOIS

April 8 to 11, 1929

VOLUME XXXVII

Edited by ROBERT E. KENNEDY

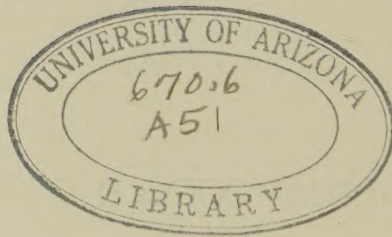
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OFFICERS
OF THE
American Foundrymen's Association
INCORPORATED

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FRED ERB

Erb-Joyce Foundry Co., Detroit, Mich.

Vice-President

N. K. B. PATCH

Lumen Bearing Co., Buffalo, N. Y.

Executive Secretary-Treasurer

C. E. HOYT

Adams-Franklin Bldg., Chicago, Ill.

Technical Secretary

R. E. KENNEDY

Adams-Franklin Bldg., Chicago, Ill.

MEMBERS OF THE BOARD OF DIRECTORS

(In addition to the President, Vice-Pres., and Executive Secy.)

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West Lynn, Mass.

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National Cast Iron Pipe Co.,
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H. COLE ESTEP,
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Ohio Brass Co.,
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S. W. UTLEY,
The Detroit Steel Casting Co.,
Detroit, Mich.

DELOS H. WRAY,
Henry Wray & Son, Inc.,
Rochester, N. Y.

Summary of the Proceedings of the 33rd Annual Meeting

The thirty-third annual convention of the American Foundrymen's Association and the twenty-second annual exhibit was held at the Stevens Hotel, Chicago, April 8 to 11, 1929. There was a registered attendance of 3,214 men and 189 ladies.

This, the fourth annual meeting of the association to be held in Chicago, was unusual in that all activities were held under one roof. There was marked interest and the attendance at technical sessions was greater than at any previous meeting.

The technical exhibit, located on the third floor where all meetings were held, included demonstrations of sand testing and control equipment, and an exhibit of the patterns and castings made by foundry apprentices entered in the national contest sponsored by the A. F. A. The increasing interest in this contest was strikingly shown by the wide distribution of entries. Exhibits of castings and patterns were made by apprentices from the following organizations:

FOUNDRIES OF THE MILWAUKEE BRANCH, NATIONAL METAL
TRADES ASSN.

FOUNDRIES, MEMBERS OF THE QUAD CITY FOUNDRYMEN'S
ASSN. AND PHILADELPHIA FOUNDRYMEN'S ASSN.

FOUNDRIES OF EAST CHICAGO, IND., AND HARVEY, ILL.,
DISTRICTS.

WESTINGHOUSE ELECTRIC & MFG. CO., SOUTH PHILADEL-
PHIA, PA.

GENERAL ELECTRIC CO., WEST LYNN, MASS., AND SCHENEC-
TADY, N. Y.

BARTLETT HAYWARD CO., BALTIMORE, MD.

PETTIBONE, MULLIKEN CO., CHICAGO, ILL.

BUILDERS IRON FOUNDRY, PROVIDENCE, R. I.

BROWN & SHARPE MFG. CO., PROVIDENCE, R. I.

Ladies' Entertainment, in Charge of Hostess

On Tuesday a luncheon was given the ladies in the Wedgwood Room of Marshall Field & Co., followed by a style show. Wednesday morning the ladies visited the Field Museum and in the evening the annual banquet, reception and dance which was held in the Grand Ballroom of the Stevens Hotel. Special shopping tours were arranged for during the week. The reception and entertainment for the ladies was in charge of the official A. F. A. hostess, Miss Fannie M. Baldridge.

Exhibitors' Dinner

On Monday evening the second annual exhibitors' dinner was held with an attendance of about 300. H. W. Standart, President of the Foundry Equipment Manufacturers' Association, presided.

Technical Sessions

A total of twenty-three sessions were held during the week. Of these sessions three were round table luncheon meetings and eight were meetings connected with the short courses for foundry operators for both steel and iron.

There was an attendance of about 100 at each of the round table discussion meetings. Following the luncheons, these meetings were thrown open to informal discussion and from the interest displayed it is considered that this type of meeting will play a prominent part in conventions of the future. The shop operation courses also proved popular and the result bore out the predictions made following the first of these, which were held at the Philadelphia convention in 1928.

At the technical sessions there were 34 papers and 9 committee reports presented. The classification of the papers was as follows:

Steel	2	General Interest	16
Malleable	3	Divided into	
Non-Ferrous	3	Apprentice Training	2
Cast Iron	11	Foreman Training	5
		Materials Handling	2
		Costs	1
		Cores	2
		Scrap Use	1
		Sand Control	3

An innovation in connection with the technical program was the holding of the first evening technical session, this being on sand control. The attendance was approximately 400 at this session.

The reports of the sessions follow :

Opening Session and Annual Business Meeting
Monday, April 8, 2:00 P. M.

The opening session of the Annual Business Meeting was held on Monday, April 8th, at 2:00 P. M., President S. T. Johnston presiding.

Executive-Secretary C. E. Hoyt read his report which will be found on page 21. It was moved by H. S. Simpson that the report be accepted as read and that the recommendations on the reclassification of members and increase in dues for certain classes of members be referred to the Board of Directors for their consideration. The motion was seconded and unanimously adopted.

N. K. B. Patch, Vice-President-elect, made a report as Chairman of the Divisional Correlation Committee, reviewing the purposes of the new Divisional Organization and explaining certain activities which were proposed for the coming year. The Chairmen of the newly created Divisions were introduced.

Activities of the various committees were briefly reviewed by :

Fred Erb, Chairman of the Committee on Molding Sand Research.

H. Cole Estep, Chairman of the Committee on International Relations.

C. J. Freund, Chairman of the Committee on Training of Apprentices.

A. E. Hageboeck, Chairman of the Committee on Foundry Costs.

Following the presentation of these reports, Dr. S. G. Werner, President of the International Committee of Foundrymen and President of German Iron Founders' Association, was then called upon by President Johnston to address the meeting, which he did, expressing appreciation on behalf of himself and the German Founders' Association for the courtesy extended to their

members while in this country. He also spoke a few words about the International Congress which is to be held in Dusseldorf, Germany, in 1935.

Secretary Hoyt announced the names of the winners of the 1928 Philadelphia Convention Papers Contest to receive prizes as authorized by the Board of Awards. These were as follows:

H. A. Mason of the Gould Coupler Company, for his paper on Reducing New Sand Consumption in Steel Foundries.

W. F. Roeser and H. T. Wensel of the Bureau of Standards, for their joint paper on Temperature Measurements of Molten Cast Iron.

O. W. Ellis of the Westinghouse Electric & Manufacturing Company, for his paper on Effect of Lead on the Mechanical Properties of a Complex Brass.

The reports of the judges of the Apprentice Molding and Pattern Contests were then read. These were as follows:

STEEL MOLDING CONTEST

To the Members of the American Foundrymen's Association:

We, the members of the Committee appointed to judge the castings entered in the 1929 Apprentice Steel Molding Contest of the A. F. A., after individually grading the entries according to the scoring method provided by the Apprentice Committee of the A. F. A., recommend that the prizes be granted as follows:

First: G. Warnek, Sivyer Steel Casting Co. Milwaukee, Wisconsin.

Second: H. Paepke, Falk Corporation, Milwaukee, Wisconsin.

Third: M. Gadzala, Hubbard Steel Foundry Co., East Chicago, Indiana.

Respectfully submitted,

GEORGE FISHER

C. N. RING

J. A. MARR

GRAY IRON MOLDING CONTEST

To the Members of the American Foundrymen's Association:

We, the members of the Committee appointed to judge the castings entered in the 1929 Apprentice Gray Iron Molding Contest of the A. F. A., after individually grading the entries according to the scoring method provided by the Apprentice Committee of the A. F. A., recommend that the prizes be granted as follows:

First: N. F. Chapman, Brown & Sharpe Mfg. Co., Providence, Rhode Island.

Second: C. W. Hansen, Brown & Sharpe Mfg. Co., Providence, Rhode Island.

Third: A. Lachowicz, Calumet Foundry Company, Indiana, Harbor, Indiana.

Respectfully submitted,

W. CURETON

L. WECKERLY

C. L. LARSON

PATTERN MAKING CONTEST

To the Members of the American Foundrymen's Association:

We, the members of the Committee appointed to judge the patterns entered in the 1929 Apprentice Pattern Making Contest of the A. F. A., after individually grading the entries according to scoring method provided by the Apprentice Committee of the A. F. A., recommend that the prizes be granted as follows:

First: H. Smith, Milwaukee Pattern & Mfg. Company, Milwaukee, Wisconsin.

Second: V. Tatewosian, Brown & Sharpe Mfg. Company, Providence, Rhode Island.

Third: S. Marotto, Fletcher Works, Philadelphia, Pennsylvania.

Respectfully submitted,

G. A. ROSS

CHAS. JOHNSON

WM. BECK

ED. SABEY

S. OBERMAYER CONTEST

The report of the judges of the S. Obermayer contest was read as follows:

To the Members of the American Foundrymen's Association:

We, the committee appointed to judge the entries in the 1929 Obermayer Prize Contest of the American Foundrymen's Association, recommend that Valmore N. Blais, apprentice molder, Brown & Sharpe Mfg. Company, Providence, Rhode Island, be granted the prize for his entry, a ladle skimming device.

Respectfully submitted,

GEO. FISHER

C. N. RING

J. A. MARR

Following the reading of these contest reports, it was moved that they be accepted and that the awarding of prizes as recom-

mended by the judges be referred to the Board of Directors in accordance with the provisions of the By-Laws.

The motion was seconded and unanimously adopted.

President Johnston then called upon Secretary Hoyt to read the report of the Nominating Committee. This report announced the following candidates for officers and directors:

For president, to serve one year—Fred Erb, Erb-Joyce Foundry Company, Detroit, Michigan.

For vice-president, to serve one year—N. K. B. Patch, Lumen Bearing Company, Buffalo, New York.

For directors, to serve three years each:

Harold S. Falk, Falk Corporation, Milwaukee, Wisconsin.

S. T. Johnston, S. Obermayer Company, Chicago, Illinois.

Frank J. Lanahan, Fort Pitt Malleable Iron Company, Pittsburgh, Pennsylvania.

Arnold Lenz, Chevrolet Motor Company, Saginaw, Michigan.

Delos H. Wray, Henry Wray & Son, Inc., Rochester, New York.

The Secretary stated that no other nominations had been made, as provided for in the By-Laws, and moved that the candidates named be declared elected to the respective offices for which they were nominated, they to assume office at the annual Board meeting. Motion seconded and carried.

President Johnston announced the personnel of the Committee on Resolutions for the convention. The committee was composed of the following:

N. K. B. Patch, Chairman; D. M. Avey; A. E. Howell.

Secretary Hoyt presented the report of the Board of Directors, recommending that Mr. J. H. Whiting, charter member of the Association and donor of the J. H. Whiting medal, be elected to honorary membership.

It was moved and carried that Mr. Whiting be so elected.

President Johnston called upon Secretary Hoyt to make certain announcements regarding convention activities.

Included in these announcements was one that the 1930 convention is to be held at Cleveland, Ohio, the week of May 12th at the Cleveland Public Auditorium.

There being no further business, the meeting was adjourned to reconvene Thursday, April 11th.

Adjourned Annual Business Meeting
Thursday, April 11, 3:00 P. M.

President S. T. Johnston presiding.

The following report of the Committee on Resolutions was read and approved.

Your committee appointed by President Johnston begs to report:

"The 33rd Annual Convention of the American Foundrymen's Association, unique in many features, long will be remembered with pleasure by those who have attended.

"We desire to express to the foundrymen of the Chicago district, to the Committee on Conventions of the Association of Commerce of Chicago, and to the staff of the Stevens, our deepest appreciation for the hearty cooperation, splendid hospitality, and unexcelled sincerity of their reception and entertainment during the week. The headquarters city of the American Foundrymen's Association has strengthened the high regard in which it is held by the Association members.

"We wish to acknowledge with greatest appreciation the splendid work of the numerous technical committees, the authors of papers and reports, and those who have contributed so largely from the fund of their experience to the general advancement of the industry during the Convention.

"To those manufacturers of foundry equipment and supplies who have assembled and presented to the foundry public the results of their study and advancement in manufacturing methods, we extend our thanks.

"Further, your Committee on Resolutions reiterates the high esteem in which the members of the Association hold their President and all other officers and directors charged with the responsibility for the continued work and accomplishments of this organization."

Respectfully submitted,

N. K. B. PATCH
D. M. AVEY

The following message of greetings, prepared by the Committee on Resolutions, was presented, received and recommended to the Board of Directors for favorable action:

To the Council and Members of the Institute of British Foundrymen
Greeting:

"The American Foundrymen's Association in Convention assembled, acting with and for its membership representing twenty-five hundred American Foundrymen, and by unanimous action of its Board of Directors, extends greetings to the Third International Foundrymen's Congress.

"Many members of the American Foundrymen's Association journeying to London this June exemplify the spirit of friendly emulation which

is fostered by the annual exchange of papers between the great foundry organizations in Europe and America. A warm feeling of fellowship in the work and accomplishments of the industry which we all serve is intensified by these triennial meetings.

"Best wishes are extended for the complete success of the Third International Congress.

"We instruct that this greeting be recorded on our minutes and that a copy in permanent form be delivered to the Officers and Members of the Institute of British Foundrymen, thus conveying our continued high esteem and appreciation for their hospitality on all occasions.

THE AMERICAN FOUNDRYMEN'S ASSOCIATION

S. T. JOHNSTON, *President*

C. E. HOYT, *Secretary*"

Annual Convention

Chicago, April 11, 1929.

There being no further business to transact, the President declared the final adjournment of the 1929 annual business meeting of the American Foundrymen's Association.

Session No. 1—Steel Foundry Shop Operation Course
Monday, April 8, 4:00 P. M.

The subject discussed at this meeting was Pouring Practice, the chairman being C. N. Ring of the Electric Steel Founders' Research Group. No formal papers were presented.

Session No. 2—Gray Iron Foundry Shop Operation Course
Monday, April 8, 4:00 P. M.

The subject discussed at this meeting was that of Gates and Risers, the chairman being H. W. Dietert. No formal papers were presented.

Session No. 3—Foundry Costs
Tuesday, April 9, 10:00 A. M.

Presiding, A. E. Hageboeck. The meeting was addressed by E. T. Runge of Cleveland, Ohio, on the subject, Practical Aspects of the Value of Foundry Cost Methods. Following this address, those in attendance submitted cost estimate examples and the variation in the answers to these estimates were discussed during the balance of the meeting.

*Session No. 4—Steel Founding
Tuesday, April 9, 10:00 A. M.*

Chairman, Past President S. W. Utley. The following papers and committee reports were presented:

REPORT OF INVESTIGATION OF EFFECTS OF PHOSPHORUS AND SULPHUR IN STEEL, by R. A. Bull, A. F. A. representative on the Joint Committee to Investigate the Effects of Phosphorus and Sulphur in Steel.

ALLOY STEEL CASTINGS, by D. Zuege, Sivyer Steel Casting Co., Milwaukee, Wis.

EFFICIENT STEEL CASTING GRINDING, by F. A. Lorenz, Jr., American Steel Foundries, East Chicago, Ind.

REPORT OF COMMITTEE ON STEEL CASTINGS, presented by A. H. Jameson, Chairman of the committee.

The report of the Committee on Steel Castings was accepted as read and referred to the A. F. A. Board of Directors for final action.

*Session No. 5—Cast Iron Metallurgy
Tuesday, April 9, 10:00 A. M.*

Chairman, Dr. H. W. Gillett. The papers and reports read were as follows:

REPORT OF A. F. A. SPECIAL COMMITTEE ON CAST IRON RESEARCH, presented by James T. MacKenzie, Chairman of the special committee.

QUALITY OF PIG IRON AND CAST IRON AS AFFECTED BY BLAST FURNACE PRACTICE, by A. L. Boegehold, General Motors Corp., Detroit, Mich.

A motion was passed requesting the A. F. A. to publish any further data Mr. Boegehold might submit.

*Session No. 6—Uniform Non-Ferrous Cost Methods—Round
Table Luncheon and Meeting
Tuesday, April 9, 12:30 P. M.*

Chairman, E. B. Hazen. No formal papers were read at this meeting, the discussion being limited to the need for development

of groups of non-ferrous foundrymen to adopt uniform non-ferrous cost methods.

*Session No. 7—Steel Foundry Practice—Round Table Luncheon
and Meeting*

Tuesday, April 9, 12:30 P. M.

Chairman, R. J. Doty. Discussion of general steel foundry practice problems.

*Session No. 8—General Foundry Management and Practice
Tuesday, April 9, 2:00 P. M.*

Presiding, Vice-President Fred Erb. At this time the following papers were presented and discussed:

USE OF SCRAP IN GRAY IRON, MALLEABLE, AND ELECTRIC STEEL MIXTURES, by E. K. Smith and F. B. Riggan, Stockham Pipe & Fittings Company, Birmingham, Alabama.

BAKING PRACTICE FOR OIL SAND CORES, by H. L. Campbell, University of Michigan, Ann Arbor, Michigan.

CORE OIL TESTING AND SPECIFICATIONS, by V. A. Crosby, Studebaker Corporation, South Bend, Indiana.

SAFETY AND SANITATION IN THE FOUNDRY, by F. H. Elam, American Steel Foundries, Chicago, Illinois.

Session No. 9—Sand Control Fundamentals

Tuesday, April 9, 4:00 P. M.

Chairman, Past President R. A. Bull. This session took the place of the iron and steel shop operation courses which were originally scheduled for this time. The following talks were given and discussion followed.

SAND CONTROL IN A BRASS FOUNDRY, by W. F. Graham, Ohio Brass Company, Mansfield, Ohio.

SAND CONTROL IN A MALLEABLE FOUNDRY, by W. Ranis, Union Malleable Iron Company, Moline, Illinois.

SAND CONTROL IN GRAY IRON FOUNDRIES, by R. F. Harrington, Hunt-Spiller Mfg. Corp., Boston, Massachusetts.

REDUCTION OF SCRAP, by E. W. Smith, Crane Company, Chicago, Illinois.

Session No. 10—Sand Control—Practice and Research Developments. Tuesday, April 9, 7:30 P. M.

Chairman, Past President R. A. Bull. The following committee reports were presented:

REPORT OF TECHNICAL DIRECTOR OF THE COMMITTEE ON MOLDING SAND RESEARCH, by H. Ries.

REPORT OF COMMITTEE ON CONSERVATION AND RECLAMATION, by R. F. Harrington, Chairman.

REPORT OF COMMITTEE ON GRADING. In the absence of Chairman A. A. Grubb, this report was submitted by title.

REPORT OF COMMITTEE ON TESTS, by H. Ries.

The report of the Committee on Tests was supplemented by the report of the Sub-Committee on Core Tests, by E. R. Young, Chairman of the Sub-Committee.

The above committee reports were approved as read.

The following papers were presented and discussed:

SOUND CASTINGS, by R. W. Kurtz, Jas. B. Clow and Sons, Newcomerstown, Ohio.

SOME EXPERIMENTS IN SAND CONTROL, by E. F. Wilson, Jefferson-Union Company, Lockport, New York.

THE REFRACTORINESS OF FOUNDRY SANDS, by J. F. McMahon, Mines Branch, Department of Mines, Ottawa, Ontario, Canada.

*Session No. 11—Non-Ferrous Foundry Practice
Wednesday, April 10, 10:00 A. M.*

Chairman, Past President G. H. Clamer. The following papers and committee report were read and discussed:

SOME PRACTICAL PROBLEMS IN THE BRASS FOUNDRY, by H. J. Roast, National Bronze Company, Ltd., Montreal, Quebec, Canada.

ELECTRIC ARC FURNACES IN GENERAL JOBBING BRASS FOUNDRY, by J. B. Meier, F. & H. Foundry Company, Newark, New Jersey.

AN OPEN-FLAME HEARTH-TYPE FURNACE FOR MELTING ALUMINUM AND ITS ALLOYS, by R. J. Anderson, G. E. Hughes and M. B. Anderson, Fairmont Mfg. Company, Fairmont, West

Virginia. In the absence of the authors, this paper was presented by title.

REPORT OF CHAIRMAN OF THE DIVISION OF NON-FERROUS FOUNDRY PRACTICE—J. W. Bolton, Chairman of the Division, gave an informal oral report outlining certain activities which are planned for the Division.

Session No. 12—Iron Founding Practice
Wednesday, April 10, 10:00 A. M.

Chairman, R. F. Harrington. The following papers and report were presented and discussed:

A STUDY OF 36-INCH CUPOLA OPERATION, by F. B. Coyle, International Nickel Company, New York City.

AN ANALYSIS OF 54-INCH CUPOLA PERFORMANCE, by E. E. Marbaker, Whiting Corporation, Pittsburgh, Pennsylvania.

SCIENCE HAND IN HAND WITH LABOR, by Frank Hudson, Chief Metallurgist, Glenfield and Kennedy, Ltd., Kilmarnock, Scotland. Annual exchange paper of the Institute of British Foundrymen. In the absence of the author, this paper was presented in abstract form by Oliver Smalley.

Session No. 13—Materials Handling
Wednesday, April 10, 10:00 A. M.

Chairman, D. M. Avey. Two papers were presented and discussed. They were:

MOLD HANDLING, by R. J. Heisserman, Link-Belt Company, Philadelphia, Pennsylvania. In the absence of the author, this paper was presented by J. J. Hartley of the Chicago office of the Link-Belt Company.

MATERIALS HANDLING IN THE FOUNDRY, by A. Walton, Philadelphia, Pennsylvania.

Session No. 14—Non-Ferrous Foundry Practice—Round Table Luncheon and Meeting
Wednesday, Apr. 10, 12:30 P. M.

Chairman, J. W. Bolton. No papers were presented at this meeting, the time being devoted to informal discussion of shop problems.

Session No. 15—Foreman Training
Wednesday, April 10, 2:00 P. M.

Chairman, G. E. Bergstrom. This meeting was in the form of a symposium. Short papers on foreman training were presented by the following:

W. F. Coleman, W. A. Jones Foundry & Machine Company, Chicago, Illinois.

A. R. Peirce, Director, Dept. of Industrial Education, National Metal Trades Association, Chicago, Illinois.

M. H. Mellen, Supervisor of Education, General Electric Company, West Lynn, Massachusetts.

G. A. McGarvey, Agent, Industrial Education, Federal Board for Vocational Education, Washington, D. C.

A. D. Lynch, Personnel Director, Ohio Brass Company, Mansfield, Ohio.

L. A. Hartley, Educational Director, National Founders' Association, Chicago, Illinois.

Following the presentation of these papers the meeting was thrown open to general discussion.

Session No. 16—Steel Foundry Shop Operation Course
Wednesday, April 10, 4:00 P. M.

Chairman, A. C. Jones. Subject, Core Room Practice.

Session No. 17—Gray Iron Foundry Shop Operation Course
Wednesday, April 10, 4:00 P. M.

Chairman, J. T. MacKenzie. Subject, Cupola Control.

Session No. 18—Malleable Iron Foundry Practice
Thursday, April 11, 10:00 A. M.

Chairman, Director-elect, F. J. Lanahan. The following papers were read and discussed:

PRACTICAL ASPECTS OF WHITE FRACTURE MALLEABLE IRON, by D. P. Forbes, Rockford-Northwestern Malleable Corp., Rockford, Illinois.

CONTROLLING THE ATMOSPHERE IN MALLEABLE ANNEALING OVENS, by W. F. Graham, Ohio Brass Company, Mansfield, Ohio.

SHRINKAGE IN MALLEABLE IRON CASTINGS, by H. A. Schwartz, National Malleable and Steel Casting Company, Cleveland, Ohio.

REPORT OF CHAIRMAN OF DIVISION OF MALLEABLE IRON FOUNDRY PRACTICE, by S. MacKay. Mr. MacKay outlined some of the activities of the Division for the coming year.

*Session No. 19—Apprentice Training
Thursday, April 11, 10:00 A. M.*

Chairman, L. A. Hartley. The papers presented at this session were:

WHY WE TRAIN APPRENTICES, by J. A. Davies, Westinghouse Electric and Mfg. Company, Philadelphia, Pennsylvania.

HOW WE TRAIN APPRENTICES, by A. M. Cornell, Pettibone-Mulliken Company, Chicago, Illinois.

Following the presentation of these papers, the discussion was led by A. E. Harrison of the Allis-Chalmers Mfg. Company.

Session No. 20—Malleable Iron Foundry Practice—Round Table Luncheon and Meeting. Thursday, April 11, 12:30 P. M.

Chairman, S. Mackay. As there were no formal papers presented at this meeting, the time was given over to informal discussion of general foundry problems.

*Session No. 21—High Test Cast Iron
Thursday, April 11, 2:00 P. M.*

Chairman, H. F. Moore. This meeting was in the form of a symposium. Papers on European developments of high test cast iron were read first. They were by the following:

E. E. Marbaker, Whiting Corporation, Pittsburgh, Pennsylvania.

Fritz Meyer, National Radiator Company, Johnstown, Pennsylvania.

R. P. Lemoine, Paris, France. Annual exchange paper of the French Foundry Technical Association. In the absence of the author, this paper was presented by R. S. McCaffery.

Papers on American developments of high test cast iron were presented by the following:

F. B. Coyle, International Nickel Company, New York, N. Y.

R. S. MacPherran, Allis-Chalmers Mfg. Company, Milwaukee, Wisconsin.

H. Bornstein, Deere & Company, Moline, Illinois.

O. Smalley, Brooklyn, New York.

E. J. Lowry, Detroit, Michigan.

Following the presentation of these papers, the general subject of high test cast iron was discussed.

Session No. 22—Steel Foundry Shop Operation Course

Thursday, April 11, 4:00 P. M.

Chairman, J. H. Hall. Subject, Heat Treatment of Steel Castings.

Session No. 23—Gray Iron Foundry Shop Operation Course

Thursday, April 11, 4:00 P. M.

Chairman, C. J. Scullin. Subject, Cupola Control—Melting Operations.

33rd Annual Banquet American Foundrymen's Association

Stevens Hotel, Chicago, April 10, 1929

President S. T. Johnston presiding.

PRESIDENT JOHNSTON: Members of the American Foundrymen's Association, ladies and guests: This has been quite an unusual convention, inasmuch as there are things which have been done and some things that were not done, quite different from former years.

In the first place it happens that the president of your association this year, as a resident of Chicago, presides at a convention of the A. F. A. in his home city. It has been seventeen years since the president of the year had a convention in his home city. It has been a very great pleasure to me, I assure you, to have you here and to greet you as president in my own town.

Next, you may notice that at this table these gentlemen are nearly all directors of the association. In former years we have had all our distinguished visitors at the speakers' table. Following that practice we would have had Dr. Werner here. Doctor (turning to Dr. Siegfried Werner), you understand that this year a change in our policy calls for seating at the speakers' table none but our own directors and those who are to address us.

I wish to introduce the gentlemen at this table to those who do not know them. The second gentleman from the right at the end is Mr. Wray. He is a director-elect. Going down to the other end of the table, sitting next to Mr. Hoyt, whom you all know, is Mr. Falk of Milwaukee and next to him is Mr. Lanahan of Pittsburgh. Mr. Falk and Mr. Lanahan are also directors-elect. Then at my right is Mr. Fred Erb, president-elect. The second gentleman to my left is Mr. Patch, vice-president-elect, six feet five and a half inches of non-ferrous metal. At the far end of the table to the right is our technical secretary, Mr. Kennedy, whom you all know, especially you men who have been

engaged in the committee work of the association and have prepared papers for us. He is the man you come in contact with

At the other end of the table is a man I am going to get square with for once in my life, Charlie Hoyt; and I hope (referring to the applause) you will do that again when I get through with what I have to say about him. He has been giving me orders for one solid year and I have been taking them every day. I want to say that no organization of which I have any knowledge has a more efficient, conscientious, fair-minded man than we have in our executive secretary. It is a pleasure to work with him. He is a clean thinking, clean living, clean talking and clean acting man. Herbert Simpson and I have watched him pretty nearly every working day and I assure you it is a great joy and a great pleasure to work with him.

A great many of you call him "Ed Hoyt." Well, Mrs. Hoyt and the rest of you may call him "Ed" Hoyt, but he is my Charlie just the same.

In the audience I see several of our past-presidents and quite a number of the members of the various committees. We have about one hundred and thirty men who have taken a very active part in the committee work of this organization. Now it is not every organization or every association, I believe, that can rely upon men as we have done who so well, so faithfully, and so wonderfully do their work as our committee men have done. These men have been very diligent and very active in their co-operation with the officials of the organization. I want to pay my respects to them here tonight.

In addition, of course, we have in our membership the men of the equipment and supply association and our exhibitors. These men have staged for us again an unusual exhibit, although a small one. They met the requirements. We asked them to limit it and they did so, very cheerfully, very willingly, and as in all association affairs they worked very well with us. Again I am going to refer to an unusual happening this year. For the first time in the thirty-three years of our existence, the association has for its president a representative of the exhibitors and of the equipment and supply men's association. That is very unusual and I am sure is appreciated by all the men in that group.

I have referred to the many men, about one hundred and fifty, who take part in the work of the association, do it well, do it generously, and take it out of their own time. That they are doing all this I happen to know because the secretaries send me copies of many letters they write and a great many of the members of committees send me copies of the letters they write. The result is a large stack of correspondence which I will be very glad to turn over to you, Mr. Erb. It is wonderful to me what these men have done and it means this: ours is an educational association and you are all working, all doing something for the education of foundrymen. Now the effort and energy put into this is simply remarkable and I assure you that none of you who have not come into personal contact with the various members of committees can know what is going on all the time.

We have various committees; one, for instance, the Apprentice Training Committee. Secretary Hoyt and I were at Moline two weeks ago and attended a meeting of the Quad City Foundrymen's Association. One hundred and thirty were present that night, among them a group of apprentices. They were a fine looking lot of boys. I just thought that here is an apprenticeship system much different from those that formerly existed. These boys are really getting an education. Today I saw a group of apprentices coming into our exhibit. I was glad to shake hands with them all. They were molding and pattern making apprentices. They looked as fine as many a bunch of fraternity fellows that you college men have associated with.

Now I say this association is educational. We are engaged in educational work. I want to read you something. It is from the *Valve World*, a house organ published by one of our members, the Crane Company. We have heard from several Crane Company men at our meetings. Perhaps the author of this is here tonight. It is so good that I am going to read it:

"There died recently, at the age of 78, a man who spent practically all his life in going to school. He began at the usual school age, entered college and was graduated with honors. Then he took up postgraduate work in pursuit of a higher degree, and he kept on accumulating capital letters to affix to his name (and it was a long name) until illness compelled him to quit school and this life at about the same time.

"Was this man educated? We don't know. The world does not know. All that is known is that he spent so much time and effort pouring education into himself that he had no time to pour any of it out. Presumably he filled himself with formal knowledge, but what that knowledge was worth to him or to his fellows is a problem he took with him when he left this world.

"It is not of record that this man used his acquired knowledge in teaching. No book bears his name as its author. He was not found on a lecture platform. He was not a publicist nor a welfare worker. He does not seem to have made any practical use of his seventy years of education. He absorbed, but he did not give out. He gorged himself on the fruits of service, but did not serve. He acquired, but did not distribute. He was a mental miser.

"Knowledge is power, but only when it is used. Stored knowledge is like stored water, useless in storage but of vast might when put into service. The acid test of any and all education is not how much of it one may absorb, but the use to which it may be put. All the degrees in the world strung after a man's name will not make him of any use to himself or to the world unless he transmutes his knowledge into some sort of service to mankind. Many a man, who never had a year of formal education in his life, is doing more for the world every day than this 'record' student did in all of his 78 years."

Now we do not have that aim or idea in our organization. I can see before me a great many men who know a great deal about foundry matters and are giving out that knowledge. I think it is a good deal better to say that the more liberal giver you are the better you will be. That is a funny thing for a Scotchman to say, but I tell you it is my observation that the more you give, the more you get.

Now I told Charlie Hoyt that I was going to make a speech tonight. He said "Where did you get the idea that you were expected to make a speech?" I said "Why I have been thinking of that all year," and here tonight I pick up the program and see "Presiding, S. T. Johnston," and there is not a blamed word about my making a speech. I find I have been worrying for a year about a thing I was not supposed to do.

When President Hoover took his oath of office, he kissed the Bible at a most remarkable passage, "Where there is no vision, the people perish." Now whether that was accidental or not, does not make a bit of difference. That statement is very true in national affairs. We know it is very true in all altruistic endeavors. Whatever we do for others, we have to have some vision of what we are doing. We have to have it in our villages, in our cities, in our associations, and I am sure it applies just as well to an organization of our kind. In observing our program and efforts one must realize that this Association has a vision, the vision of better work, more easily done, better done, in better surroundings and pleasanter conditions, a happier life. The vision of making life for men and women pleasanter, happier and more profitable in all respects. That is the vision, I think, of the American Foundrymen's Association. If it is not, let us get it, let us have some vision that is worth while. I thank you. I will now call upon Past-President G. H. Clamer.

PRESENTATION SPEECH BY GUILLIAM H. CLAMER

Mr. President, Mrs. Jones, Ladies and Gentlemen: It was with great pleasure that I accepted the invitation of the Board of Awards to formally present posthumously the Joseph S. Seaman Gold Medal awarded to my old-time and honored friend, Jesse L. Jones. I was happy to accept that I might in my crude and humble way express in the limited time at my disposal, a few words to record my personal estimate of the high character and ability of our departed friend. My own estimate I know reflects completely also the estimate of all his friends and co-workers in the metallurgical and foundry industries.

It was my good fortune to know Jesse Jones over a period of more than twenty years. I came in contact with him frequently at technical meetings. He was on many committees. His service on committees was constantly sought, and it was a rare occasion indeed to find a gathering of men, in the fields of the activities in which he was engaged, without him present. It was one of his outstanding traits to be faithful in all things and particularly in any work that was assigned to him. Always ready and willing—no wonder he was so much called upon. He

was a remarkable investigator. Perchance he might come to a meeting a little late, or again he might ask to be excused early. We all knew the reason why. He was off on some investigation. It was his habit to couple with his committee work investigations for his company. He had heard or read of some work that was of interest to his company or perhaps of interest in connection with the work of one of his technical committees. No matter how early or how late it might be, he seldom passed an opportunity to investigate and to compare notes with the other fellow.

His personality radiated to a remarkable degree, kindliness, earnestness, steadfastness, sincerity, modesty and ability. It is therefore no wonder that those from whom he sought information should be so ready to impart to him in exchange such knowledge and experience as they possessed. His co-workers always welcomed the opportunity of getting him in a quiet nook about the hotel during a technical gathering. They knew they would always receive more from Jesse L. Jones than they were able to give. His information or suggestions were always given in a spirit of extreme modesty—never in a boastful or commanding manner. His feet were always on the ground. Yes, he had imagination too—lots of it. He saw possibilities and he steadfastly pursued the course that he believed would lead him to the solution of his problem. He was not apt to be lead into unfruitful fields. If he was he was just as frank in telling of his failures as he was of his successes.

Mr. Jones received his elementary education in the Martin's Ferry Ohio High School, and his technical education at the Ohio State University. We always thought of him not as a "high-brow" scientist, but as a practical man, a man of applied science.

His technical education at the Ohio State University equipped him well for his life's work. He had a thorough understanding and kept abreast of all the rapid advances made in the field of science in which he worked. He wished to acquaint himself with these advances not for the mere joy of theoretical understanding but for practical application.

Prior to attending college he served an apprenticeship, working as a molder in the iron foundry of Spence Baggs & Com-



JESSE LEE JONES

pany, Martin's Ferry, Ohio. During his college course he had charge of the experimental iron foundry of the University. With the practical knowledge thus gained he was able to talk to foundrymen in their own language—the language of practical understanding that commanded their utmost respect.

After graduation short periods were spent as assistant chemist with Dr. N. W. Lord, Ohio State chemist, and the Junction Iron and Steel Company of Mingo Junction, Ohio, makers of bessemer pig iron and steel. He was also employed by the West Penn Steel Company of Pittsburgh, makers of open hearth steel.

In 1893 Mr. Jones became associated with the William Cramp & Sons Ship & Engine Building Company of Philadelphia, as metallurgist. It was during this employment in my home town that I first became acquainted with him. While connected with that company he aided in the development of Parson's manganese bronze, hydraulic bronze, white brass and other non-ferrous alloys on a commercial basis. He also supervised the chemical and physical testing work of the I. P. Morris branch of the Cramp Company, which company has constructed some of the largest and most important hydraulic machinery installations in the United States and Canada.

After he left the Cramp Company, I had an opportunity of having him become associated with me in business. I considered it complimentary that he should have expressed such a desire. Conditions with me at the time were not such that I could offer him a satisfactory proposal, so did not make one to him. I have always regretted, during the many years that followed, that I did not have the advantage and great pleasure of close business relationship with him. Mr. Jones soon after accepted a position with the Westinghouse Electric & Mfg. Company. That was in 1903. This position he held at the time of his death. He there had charge of the chemical and physical testing work which has been largely related to the operation and products of the Westinghouse Company iron, steel, brass, and malleable foundries.

In his life work it will be noted that he had practical experience in all branches of the foundry industry. The majority of foundrymen have a knowledge of but one branch of the

industry. In connection with other engineers of the Westinghouse Company, he developed a copper refinery, copper rolling mill, die casting plant and a scrap reclamation and smelting plant.

Mr. Jones wrote many technical papers. These papers always contained information of practical importance. The subjects covered a wide range, information about special alloys, heat treatment effects, methods of chemical analysis, description of apparatus for electro analysis, alloying problems, bearings, babbitt metal, metal conservation, etc.

He was an associate editor of the *Metal Industry* and wrote for the *American Machinist*. He prepared also a booklet for the International Correspondence School on brass foundry work. We, in the non-ferrous industry, always claimed him as our own, but of more recent years he devoted much time and study to gray iron. He was chairman of the important A.F.A. Committee on Gray Iron. The work of this committee he pursued vigorously and offered many practical and constructive suggestions. He also served as a director of the A.F.A. He was a past president of the American Institute of Metals, and a member of the executive committee of the joint committee on molding sand research. He was a member of many committees of the American Society for Testing Materials, and of the advisory committee on non-ferrous alloys of the Bureau of Standards. He was an honorary member of the American Electro-platers' Society.

One of his chief diversions was the study of birds. He loved the birds. He knew their habits and their songs. I had the pleasure of traveling with him in Europe as a member of the A.F.A. delegation to the first International Foundry Congress. He was often in the country lanes long before breakfast eagerly looking for some species not familiar to him. He was an authority on the subject; in recognition of this he was made an honorary member of the Audubon Society. Such information as this came not from him but from others. He was a religious man and was held in highest esteem by the members of his church.

The infirmity of which he died had been slowly creeping upon him for a long period, and finally after the most heroic

effort he was compelled to give up the work he so loved. Months before he relinquished his work, the Board of Awards had spoken of him as one eminently deserving of receiving one of the major A.F.A. awards. His life work was so outstanding that his name had come before the Board for several years. The sad and unfortunate fact is that the joy of knowing that he had been awarded the Seaman Medal was not his. He was unexpectedly claimed by death. What joy it might have given him to have had a knowledge of the high estimate placed upon the outstanding character of his life's work by his colleagues in the foundry industry. By unanimous action of the Board of Awards of the American Foundrymen's Association, ratified by its Board of Directors, I have the honor of presenting posthumously the Joseph S. Seaman medal and award to Jesse Lee Jones in recognition of his contribution to the Association and to the foundry industry.

Mrs. Jones, it gives me much pleasure to present to you the Seaman Gold Medal and a bronze replica, also the certificate of award.

I know that these shall always remain cherished possessions of your family.

REPLY BY MRS. JESSE LEE JONES

Mr. President, Mr. Clamer, Ladies and Gentlemen: It is a great privilege to be with you this evening, to hear this sincere and beautiful tribute and to accept, in behalf of my husband, this lovely token of your appreciation of his life and work. We thank you for it. We shall always cherish the memory of this tribute, we shall ever prize this Joseph H. Seaman medal, not only as a record of his achievements, but also as a mark of your affectionate regard.

For many years my husband kept a careful notebook in which he wrote quotations from his reading—thoughts which made some particular appeal, which he wished to remember. Among them I found this, "Fame follows merit as surely as the body casts a shadow, sometimes falling in front and sometimes behind." This particular shadow stretches out behind him. We all regret that this should be so. It is a grief to us to feel

that he did not know of this high honor. It would have meant so much to him. But for our comfort I would say that, to him, the satisfaction of work well done was enough compensation.

He was captain of the first football team of Ohio State University. About four years ago the members of the team were invited back to the Michigan-Ohio State game, to receive their letters, in recognition of the pioneer work they had done for college athletics. I saw the correspondence concerning this. In one of the letters my husband wrote "We played the game because we loved it and because we wished to win for our University." This was the unselfish spirit which characterized all his conduct of life. He never looked for recognition nor reward.

As Mr. Clamer has said, before my husband's connection with the Westinghouse Electric & Manufacturing Company, he was associated with the Wm. Cramp & Sons Ship & Engine Company of Philadelphia. While in that city he belonged to the United Presbyterian Church of which Dr. William M. Anderson is still pastor. At the funeral service Dr. Anderson made a very eloquent and beautiful address. In speaking of my husband's work, he said, "All the great ships that went down to the sea from the largest shipbuilding company in America were seaworthy and safe because of his care in making their metals, because he had tested them and knew that they were good." I would like to leave this thought with you for your inspiration.

In following it out we see that the metal industry, in which you are engaged, is an essential, a basic industry. On its broad foundations rest all the manufactures, all the transportation, all the commerce of the world. In the heat and dirt and labor of the foundry, in the exacting and tedious toil of the laboratory may you never forget the intrinsic value of your work. The strength and reliability of the iron, steel and aluminum, the copper, brass and bronze which you produce, determine the safety and success of our whole modern industrial life. The progress of this great mechanical age waits on your research. I believe it was because my husband so clearly visioned this that he loved his work and because he loved it he attained success in it.

We thank you again for your understanding and recognition of his service.

PRESIDENT JOHNSTON: I am sure you will all agree with me that the response of Mrs. Jones makes this still further a most unusual convention, because this is the first time in my thirty-three years of attending these conventions that I have seen a woman occupy a place on our banquet program. Mrs. Jones, we thank you very much for coming here yourself to accept this medal. It was only, I think, just last week that Mrs. Jones wrote a very beautiful letter saying that she felt it was her duty to herself and family, a boy and girl, to come here and accept this recognition of Mr. Jones' wonderful services to the metal industry. I know we all feel very much indebted to her for coming here to do this and doing it so beautifully.

Before we go any further, I am going to again do something unusual, to ask someone from the floor to speak to you. Dr. Werner, you heard why we made this arrangement at the speakers' table. You should have been up here with us tonight. I am going to ask Dr. Werner, who is president of the German Iron Foundries Association, also president of the International Committee of Foundrymen, to say something to us. The doctor speaks most beautiful English.

Dr. S. G. WERNER: Mr. President, ladies and gentlemen: I have to thank you most heartily, and in the name of my wife, for the very kind reception you have just given to us. We are very happy tonight to be with fellow foundrymen. I have had the pleasure of attending the business meeting at the start of the convention, and I had the pleasure of meeting many friends during the convention, friends that I knew at the time I was here twenty-five years ago engaged in work for the United States, and friends I have made since. We have met in Germany, we have met in France, we have met in Spain, and we have met in other countries too. This time the number of friends has increased and it is my sincere wish that this increase of friends and of friendships will stay on.

I hope, too, that this friendship is not a friendship which I alone experience, and I am sure that it will be an experience which will be made by the fellow foundrymen of all the different countries that have found a head in the formation of the International Committee of Foundrymen, of which I have the pleasure of being

the president this year, and of which Mr. Johnston will be my successor for the ensuing year. This cooperation of all the fellow foundrymen of the world will further the work which we have to do and which was so beautifully outlined by Mrs. Jones, in giving us new tasks which we have to fulfill. I am sure that most of you, or all of you feel the same, when I say that I have seldom heard in my life the work which we foundrymen have to do outlined better and more beautifully than Mrs. Jones did it tonight. Once more, ladies and gentlemen, accept our most hearty thanks for your kind reception and be sure that we will never forget the nice reception we have had here again in your beautiful and great country.

PRESIDENT JOHNSTON: Well, we made no mistake there, either, did we? Now we will continue with our program.

President Johnston then introduced Mr. A. K. Roswell, humorist, who gave a talk. Following this talk the meeting was adjourned.

Report of Executive Secretary-Treasurer

Annual Business Meeting, Chicago, April 8, 1929

The fiscal year of the Association corresponds to the calendar year and the membership statistics and financial statements presented in this report are for the year ending December 31, 1928.

Membership

The membership of the Association has increased steadily since 1912, at which time the total membership was 626, with the exception of a slight drop in 1916 and another drop during the depression in 1921 and 1922. Each year since 1922 we have reported a substantial increase. The gain during 1928, however, was less than for the five previous years.

The book membership on January 1, 1928, was 2,330. Number of members elected during the year, 218; resignations 120; delinquent 63; total lost 183. Membership on December 31st, 2,365. Net gain 35.

In our membership, which is larger than that of any other foundry organization in the country, we have a larger number of foundries in each of the four branches, gray iron, steel, malleable and non-ferrous, than the combined memberships of all other foundry associations representing each of these branches. With such an organization our responsibilities are great and our opportunities for serving the industry are limited only by the funds available for that purpose.

Finances

Since 1916 when the Association took over the handling of the exhibits, two sets of books and two separate accounts have been kept, one for the technical and one for the exhibit department. When the books were audited on January 1st, the accounts of the two departments were consolidated, in accordance with a resolution of the Board of Directors. At that time the total bank balance was \$13,595.15.

This larger than usual bank balance at the end of the year was the result of successful exhibit operations and the further fact that we were not called upon to pay, until after the first of the year, the cost of publishing the proceedings of the Philadelphia Convention. Had this been paid before the books were closed, our balance would have been less than \$9,000.

Award Funds

Our total investments in the four major and one minor award funds are \$21,520.10. On December 31st our cash in the interest account was \$1,619.75, making the total award fund assets \$23,139.26.

Exhibit Reserve Fund

This fund, started in 1919, was created to provide against any emergency or loss resulting from the operation of our large exhibits and for which the membership at large could not properly be held responsible.

On December 31st the investments in this fund amounted to \$38,079.22. Cash in interest account, \$1,679.75. The total of \$39,758.97 represents approximately 10 per cent of the total space receipts from 1919 to 1928.

Total Assets

According to the auditor's statement, our total assets on December 31st, including award and reserve fund investments, were \$80,872.52. All reserve and award fund investments are held in trust by the Harris Trust Co., Chicago.

Expenses of the Technical Department Exceed Receipts From Dues

An analysis of the books reveals the fact that in no year since the Association was incorporated in 1916, nor for several years preceding that time, has the income from dues been equal to the expenses of the technical department. From 1922 to 1925, with dues at \$12.00 per annum, the per capita cost of the operations of the technical department ranged from \$13.17 to \$16.13, a per capita deficit ranging from \$1.17 to \$4.13.

The increased membership resulting from the provisions made for additional memberships at \$7.50 reduced somewhat the

per capita cost and in 1928 it was \$12.17. The average dues, however, because of the lower rate, created in 1925, was only \$10.73, leaving a deficit of \$1.44 per capita or a total of \$3,405.60 for the year. This deficit has been met annually by entrance fees, subscriptions, appropriations from exhibit earnings and permit fees.

It is our belief that if our firm members realized this situation and were shown the possibilities of greater service to the industry through our organization if funds were available, a great majority of them would be willing to accept an increase in dues that would make it possible. It is our recommendation that consideration be given to a slight reclassification of memberships and increased dues in some classes.

A program of increased activities that we believe it would be proper for the Association, organized as it is, to undertake, has been prepared for the Board of Directors and will be considered by them at a meeting to be held at the close of this convention.

There are many things we would like to discuss in this report, a program of exhibits, the International Foundrymen's Congress, our new Committee on Castings Promotion, and above all the splendid work of many of our committees and their plans for the coming year, but time will not permit.

Committee Organization

We would mention, however, a new development in committee activities which has been initiated, this being the formation of divisions corresponding to the main branches of the casting industry. Large blue prints of charts showing this new set-up are on exhibit here. This chart is also shown in the March Bulletin. Members are urged to study these and to offer their services for committee activities in which they are interested and especially qualified to serve upon.

1929 Award

Acting upon the unanimous recommendation of the Board of Awards, the Board of Directors voted to confer upon Jesse Lee Jones the Joseph S. Seaman Gold Medal of the Association in recognition of his services to the industry and to the Association as a member, Director, and member of many committees. It

is deeply to be regretted that Mr. Jones' sudden death occurred before he was notified that this honor had been conferred upon him by his fellow foundrymen.

Appreciation

To all authors, committee members, chairmen of sessions, judges and others who have or will during this week contribute to the success of this meeting we express, on behalf of the officers and members, their thanks.

To President Johnston, who has been ever ready to advise and help, to all Directors, to Technical Secretary Robert E. Kennedy, who prepares the programs of technical meetings, to my assistant Jennie Reininga, who knows more about the details of our organization than perhaps anyone else, and to all members of our staff I wish to express sincere appreciation for their splendid cooperation and loyal support.

Respectfully submitted,

C. E. HOYT, *Executive Secretary.*

Membership Report

Book Membership January 1, 1928..... 2330

New Members:

January	11
February	11
March	33
April	34
May	59
June	8
July	3
August	4
September	3
October	17
November	26
December	9

Total 218

Resignations:

Class A	79
Class B	40
Foreign	1
Total	120

Delinquents Dropped:

Class A	13
Class B	43
Junior	6
Foreign	1

Total 63

Total Resignations and Delinquents 183

Membership by Classes:

Honorary	22
Class A	1703
Class B	556
Junior	10
Foreign	74

Total 2365

Total Membership on December 31, 1928.....2365

Report of the Manager of Exhibits

September 12, 1929.

Members of the Board of Directors,
American Foundrymen's Association.

Gentlemen:

We submit herewith a report for the commercial Exhibit held in conjunction with the 1929 Annual Convention.

From 1906 to 1926 organized exhibits were held in conjunction with each annual convention of the Association, and beginning in 1916 they were directly under the auspices of the A. F. A.

At the Directors' meeting held on the evening before the opening of the 1926 convention, it was voted to hold the next convention in the spring of 1927 without an exhibit. Many accepted this as the adoption of a definite policy of alternate year exhibits. Because of the general uncertainty as to Association policy, it was felt desirable that some definite exhibit program be adopted and at the Board meeting held the evening prior to the Philadelphia Convention in 1928 the question of adoption of a ten-year program was discussed.

No action was taken but previous to the annual meeting in Chicago, July 16, 1928, six different programs were submitted to the Directors for their consideration. At that meeting it was decided that before adopting a definite program, the plan be tried out of having a limited exhibit as a substitute for no exhibit at all on alternate years.

Accordingly such an exhibit was held in the Exhibition Hall at the Stevens Hotel during the 1929 Convention. All available space in Exhibition Hall was sold and totaled 19,736 square feet, approximately one-fourth of the average space used at the 1926 and 1928 exhibits. Exhibitors were limited in the amount of space they were permitted to have and 154 exhibitors used an average of less than 130 square feet, whereas at the two previous



PORTION OF THE 1929 EXHIBIT, STEVENS HOTEL



ONE OF THE AISLES OF THE 1929 EXHIBIT

exhibits the average amount of space used per exhibitor was 310. The total number of exhibitors was 103 less than the average number at the two previous exhibits. Power for operating equipment was available but actual production work and demonstrations with materials was restricted.

It is our feeling that this experiment proved more satisfactory to the exhibitor and more satisfying to the visitor than it was generally accepted would be the case. It is our recommendation that a similar exhibit be planned for the convention in 1931 and that at this meeting action be taken looking toward the adoption of such a program.

The income from sale of space was \$19,820, making the average price just over \$1.00 per square foot. This included the 20 per cent premium for corner locations. The income from exhibit permits was \$3,850, making the total from space and permits \$23,670.

The exhibit opened at 10:00 A. M. Monday, April 8, and the final closing hour was 5:00 P. M. Thursday, April 11. The exhibits were not open on any evening.

Respectfully submitted,

C. E. Hoyt,

Manager of Exhibits.

Auditor's Statement

January 10, 1929.

Mr. S. T. Johnston, President,
American Foundrymen's Association, Inc.,
Chicago, Illinois.

Dear Sir:

I have examined the books of the American Foundrymen's Association, Incorporated, for the year ending December 31, 1928, and submit my report.

In my opinion the balance sheet of December 31, 1928 (Exhibit A), correctly reflects the condition of the Association as at that date.

Respectfully submitted,

Robert T. Pritchard,
Certified Public Accountant.

Balance Sheet
as at December 31, 1928

ASSETS

1928

ASSOCIATION ASSETS

Furniture and Fixtures Less Depreciation Reserve.....	\$ 1,143.09
Cash in Bank.....	13,595.15
Accounts Receivable	1,327.55
Supplies on Hand.....	1,408.50
Cleveland Research Fund.....	
Prepaid Expense on Account of Exhibits.....	500.00

Total Association Assets.....\$17,974.29

AWARD FUNDS

Investments	\$21,520.10
Cash in Bank.....	1,619.16

Total Award Fund Assets.....\$23,139.26

RESERVE FUND

Investments	\$38,079.22
Cash in Bank, Etc.....	1,679.75

Total Reserve Fund Assets.....\$39,758.97

TOTAL\$80,872.52

LIABILITIES**ASSOCIATION LIABILITIES**

Loan—Harris Trust & Savings Bank.....	\$.....
Dues Paid in Advance.....	550.50
Exhibitors' Permits Paid in Advance.....	
Sand Research Fund Unexpended.....	251.81
Steel Castings Test Fund Unexpended.....	267.39
Cast Iron Research Fund Unexpended.....	3,647.59

Total Association Liabilities.....\$ 4,717.29

Surplus 13,257.00

Total\$17,974.29

AWARD FUNDS

Principal of Funds.....	\$21,000.00
Premiums on Investments.....	520.10
Unexpended Income	1,619.16

Total\$23,139.26

RESERVE FUND\$39,758.97

TOTAL\$80,872.52

Department of Exhibits—Income and Expenses—1928**INCOME**

Space Rentals	\$85,037.50	
Registration Receipts—Gate	1,594.62	
Registration Receipts—Exhibitors	1,008.00	
Interest on Bank Balances	430.84	
Total Income		\$88,070.96

EXPENSES

Advertising	\$ 5,746.10	
Auditing	200.00	
Badges	475.97	
Booth Work	4,729.27	
Building Rental	4,550.34	
Cleaning and Repairing	260.00	
Committee Traveling Expense	1,202.07	
Convention Expense	388.24	
Exchange	34.77	
Executive Secretary's Salary	2,750.00	
General Expense	122.67	
Installation Labor and Material	1,557.23	
Installation Superintendent, Etc.	2,375.00	
Insurance	568.15	
Janitor Service	791.75	
Manager's Assistant	460.00	
Manager's Salary	6,500.00	
Manager's and Assistant Traveling Expenses	3,001.74	
Office Expense	533.44	
Office Rent	2,281.88	
Postage	570.38	
Power	1,203.24	
Printing and Stationery	2,415.32	
Promotion and Publicity	1,000.00	
Registration Expense	1,524.61	
Stenography and Clerical	7,075.18	
Taxes	29.10	
Telephone and Telegraph	732.56	
Watchmen and Doormen	1,029.51	
Depreciation of Furnishings and Equipment	164.41	
	\$54,272.93	
Expenses of 1927 per Previous Report	18,272.47	
Total Expenses		72,545.40
Net Income		\$15,525.56
Appropriated:		
For Sand Research	\$ 2,500.00	
For Cast Iron Research	3,000.00	
		5,500.00
Transferred to Surplus		\$10,025.56

**Statement of Income and Expenses for the Technical Department for
the Year 1928**

INCOME		1928
Dues and Subscriptions	\$27,558.56	
Convention Registration Fees.....	1,594.63	
Exhibitors' Permits	5,975.00	
Interest on Bank Balances.....	201.92	
Total Income	\$35,330.11	
EXPENSES		
Auditing	\$.....	
Committee Traveling Expense.....	1,753.84	
Convention Expense	1,360.62	
Discount and Exchange.....	94.22	
Dues—Other Associations	57.50	
Office Expense	282.95	
Postage	2,484.48	
Printing and Stationery.....	1,511.06	
Publications	9,677.53	
Rent	780.00	
Salaries—Executive and Technical Secretaries.....	8,150.00	
Stenography and Clerical Salaries.....	1,895.97	
Telephone and Telegraph.....	43.47	
Traveling Expense	637.91	
Depreciation of Furnishings.....	67.57	
Total Expense	\$28,797.12	
Balance Transferred to Surplus.....	\$ 6,532.99	

Minutes of Annual Meeting, 1928-29 Board of Directors

AMERICAN FOUNDRYMEN'S ASSOCIATION

STEVENS HOTEL, CHICAGO,
THURSDAY, APRIL 11, 1929

Held following Annual Alumni Dinner

President S. T. Johnston presiding.

Roll Call

The following responded to roll call: President S. T. Johnston, Vice-President Fred Erb, Directors N. K. B. Patch, S. C. Vessy, L. C. Wilson, E. H. Ballard, H. Y. Carson, H. Cole Estep, A. E. Hageboeck, Wm. J. Nugent, P. J. Krentz, L. W. Olson, S. W. Utley and C. E. Hoyt.

Directors-elect Frank J. Lanahan, Arnold Lenz and Delos H. Wray; Past presidents and members of advisory board, W. R. Bean, Stanley G. Flagg, Jr., and B. D. Fuller, Past Director H. S. Simpson and Technical Secretary R. E. Kennedy were also present.

Absent—M. E. Henley, A. B. Root, Jr., and B. H. Johnson.

Approval of Minutes

It was moved that the minutes of the annual meeting of the board held in Chicago, July 16, 1928, printed in bound volume of Transactions No. 36, be approved without reading. Motion seconded and carried.

The Chair stated that the by-laws provide that the annual meeting of the board of directors shall be held within ninety days of the closing date of the convention of any year, and that this meeting was called to comply with the by-laws and to transact such business as demanded immediate attention, and then adjourn to some later date.

Motion to Dispense with Regular Order of Business

It was moved that the regular order of business be dispensed with and that the present officers and directors should hold office until final adjournment of the adjourned annual meeting of the board. Motion seconded and carried.

Report of Committee on Resolutions

The Secretary reported the resolutions which had been presented by the committee on resolutions at the adjourned annual business meeting. It was moved by Mr. Krentz that the general resolutions be accepted and

made a matter of record, and that the resolutions to the Institute of British Foundrymen be prepared for presentation to the International Foundrymen's Congress in London. Motion seconded and carried.

Resolutions on the Death of Jesse Lee Jones

The Secretary read the following resolutions adopted at a meeting of the Committee on Cast Iron Specifications:

"On January 22, 1929, Jesse Lee Jones, a member of this committee, passed away in Florida. During the period of his activity with this committee he rendered invaluable and unselfish service. More than this, as a man, he has been held in high esteem and regarded with affection by all with whom he came in contact. In passing to his final reward, Jesse Lee Jones left to us a record of honesty, of sincerity, and of manly character which will long remain an example and an inspiration to those of us who remain."

Appreciation: Mr. Ballard: "In this connection I think it would be in order to say something about the response made by Mrs. Jones at the banquet. I do not know of any man or woman that I have ever heard express the responsibility of anyone in industry better than she did, and I move that the board send her a letter expressing its appreciation." Motion seconded by Mr. Patch and carried unanimously.

Report of Letter Ballot of the Board of Awards

The Secretary, reporting for the Board of Awards, submitted the following which had been approved by letter ballot submitted to all members of the Board of Awards by the chairman on December 12, 1928:

1. The Board of Awards will handle the making of all major awards, that is, the handling of the presentation of gold medals, their acts to be approved by the Board of Directors, but that in the case of minor prizes, such as those given for papers, apprenticeship contests, etc., the Board of Awards shall appropriate a certain sum for the giving of prizes for specific objects; the Board of Directors through its appropriate committees, to set up the machinery for judging these contests; the Board of Directors to receive the reports of the judges and to authorize the giving of prizes to those designated.

2. That the money required for the minor prizes each year be taken from those award funds which are not drawn upon during that year for the presentation of a major award; that is, if the major award is taken from one major fund, the minor awards or prizes shall be spread over the other funds so as to keep them all at about the same level.

3. The Board of Awards recommends that the cash prizes given for best papers presented at any convention be awarded at the succeeding convention, the announcement of winners, however, to be made as soon as the reports of the judges have been approved by the Board of Directors.

4. That in awarding gold medals of the Association a duplicate of the

medal be made in bronze, suitably mounted, so that it can be kept on the medallist's desk if desired.

5. That the Board of Awards appropriate approximately \$200.00 from the award funds for furnishing prizes for the 1929 apprenticeship contests in gray iron molding, steel molding, and patternmaking, the first prize in each case to be a wrist watch of approximately \$50.00 value, the second \$25.00 in cash, and the third \$10.00 in cash.

6. That the Board of Awards authorize the Board of Directors to expend the sum of \$300.00 of award funds for the giving of three prizes of \$100.00 each for best papers presented at the 1930 convention presentation of prizes to be made at the 1930-convention.

Under date of December 28, 1928, Mr. Utley, Chairman of the Board of Awards, advised the Secretary that an unanimous mail vote had been cast in favor of all the above proposals submitted to the Board of Awards.

The Secretary was further instructed that it was the desire of the Board of Awards to make their recommendations in the matter of presenting a replica of gold medals in bronze retroactive, and that he was authorized to order bronze replicas of all gold medals which had been awarded. This has been done and the bronze medals have been received for distribution to medallists.

It was moved that the recommendations of the Board of Awards be approved. Motion seconded and carried.

J. H. Whiting Elected Honorary Member

The Secretary reported that on the recommendation of the Board of Awards a letter ballot had been circulated among the directors, approving the election of J. H. Whiting, a charter member of the Association and donor of the J. H. Whiting gold medal fund of the A. F. A., to honorary membership; that the recommendation of the Board had been presented to the members at the annual business meeting whereupon Mr. Whiting was unanimously elected an honorary member of the Association.

Life Memberships

The Secretary pointed out that while some of the gold medallists of A. F. A. are honorary members of the Association there are a number who still retain the status of active members, and that it had been suggested that some change in their status should be made.

The Secretary called attention to the provision in Section 2 paragraph c. of Article VIII of the by-laws, which reads as follows:

"In recognition of long or special service, or for other justifiable reasons, the Board of Directors may, by a three-fourths vote, exempt any member from payment of dues and declare him a member for life."

Mr. Olson moved that Eugene Yoncoski, John Shaw, Robert J. Anderson, John Howe Hall and E. V. Roodenay, all gold medallists of A. F. A.,

not honorary members, be elected to life membership. Motion seconded and carried.

Proposed Revision of By-laws Regarding Memberships and Dues

The Secretary reported that on March 1 he had mailed a letter to all directors and members of the advisory board, recommending for their consideration that the by-laws be revised to provide for the following classes of membership: Firm, Personal, Associate, and Honorary. He recommended further that dues of firm memberships be \$25.00, personal \$12.00, and associate memberships \$7.50.

It was further recommended that if these revisions were adopted, all firms holding memberships in A. F. A. should be given an opportunity to continue as firm members at dues of \$25.00, or have some individual with the firm continue as a personal member at dues of \$12.00, and that associate membership should be available only to those individuals affiliated with a firm member paying dues of \$25.00.

It was further recommended that all classes of membership should have the same privileges, receive the same literature, have the right to serve on committees and to hold office.

The Secretary reported that 14 of the 17 directors were on record as favoring revisions along the lines suggested, that a number on the advisory board had responded, and that five members of the committee on Casting Promotion, not directors, and from whom a response had not been requested, had replied. The secretary further reported that all replies favored the revisions and that not one reverse reaction had been received; that the general feeling was that association dues were too low and should be increased that greater activities might be supported.

The question of activities that could be engaged in was discussed. The Secretary stated that as Association finances would permit additional activities and operating them for a time, it was his recommendation that the proposed new activities be started, and that then the appeal be made for increased dues to support them.

It was moved by Mr. Vessy that the matter be referred to a committee to be appointed by the President to report at the next meeting of the directors. Motion seconded by Mr. Utley and carried.

1930 Convention and Exhibit

The Secretary reported that in accordance with authorization of the board of directors at the last meeting, negotiations had been completed and a lease entered into for the use of the Cleveland Auditorium for a convention and exhibit the week of May 12 to 17, 1930.

The rent paid would be on the basis of square feet of space occupied for commercial exhibits, and there would be a charge only for service in connection with space used for educational exhibits, and no charge for auditoriums and meeting rooms.

1929 Convention Attendance

The Secretary reported that the registered attendance at the close of the 1929 convention was 3,230, and that a check of the registration showed that more than one-third of the members had registered, that approximately 1,500 were representatives of member companies and guests, and that the total number of exhibitors' representatives was 600.

It was felt that the plan of having exhibits and meetings all in one building had proved successful with one exception, namely, the undesirability of having the hotel rooms of some exhibitors too convenient to exhibit booths. The Secretary explained that the situation at Cleveland would be similar in that meetings and exhibits would be held at the Public Auditorium, but several blocks removed from the hotels.

Code of Ethics

Mention was made of certain bad practices and unbecoming conduct on the part of representatives of companies officially participating in the convention and exhibit. A long discussion followed and a code of ethics was suggested, but no action was taken other than to decide to make this a subject for further discussion at the next meeting.

Invitation to Hold Convention in Birmingham

Director Carson requested that it be made a matter of record that he had called attention of the Board to the desirability of holding one odd year convention and exhibit in the south, and to the advantages which Birmingham offered for such a meeting.

International Foundrymen's Congress

Mr. Estep, Chairman of the Committee on International Relations, read the list of those who had signed up for the Congress, about 50 in all. For the information of the directors Mr. Estep was requested by the Chair to give a history of the organization of the International Foundrymen's Congress, which he did, and in closing he said:

"More and more the affairs of the world are being conducted on an economic and business basis, and business men should accept the responsibility for keeping peace as far as they can. We have a responsibility when we go to Europe, to represent this country in the best way we can for the purpose of promoting international friendship. I really believe that we can help in the building up of a spirit of friendliness and understanding. They have the same fundamental problems in life that we have, and I am glad to see the way this movement is going on. We have a glorious opportunity in the way of representing America in a friendly way that will contribute something to the stability of the future."

Mr. Utley moved that it was the sense of the Board that if possible the Association should be represented at the International Foundrymen's

Congress by the Executive Secretary and the Technical Secretary. Motion seconded and carried unanimously.

Apprentice Contest Report

On motion the Board approved the reports of the Committees on Apprentice Contests in steel molding, gray iron molding and pattern making, which were presented and accepted at the general business meeting, and authorized the Secretary to award prizes in accordance therewith.

On motion the meeting adjourned to meet at the call of the President.

Respectfully submitted,

C. E. Hoyt, Executive Secretary.

Approved: S. T. Johnston, President.

Minutes of Adjourned Annual Meeting, 1928-29 Board of Directors

AMERICAN FOUNDRYMEN'S ASSOCIATION

STATLER HOTEL, CLEVELAND, SEPTEMBER 12, 1929

President S. T. Johnston presiding.

Roll Call

The following Officers and Directors responded to roll call: President S. T. Johnston, Vice-President Fred Erb and Directors N. K. B. Patch, A. B. Root, Jr., S. C. Vessy, E. H. Ballard, H. Y. Carson, H. Cole Estep, A. E. Hageboeck, B. H. Johnson, P. J. Krentz, L. W. Olson, S. W. Utley and C. E. Hoyt. Absent, Martin W. Henley, L. C. Wilson and Wm. J. Nugent.

Others present were Directors-elect Frank J. Lanahan and Arnold Lenz, past presidents L. L. Anthes and B. D. Fuller and Technical Secretary R. E. Kennedy.

At the annual meeting of the Board held on the closing day of the annual convention, Thursday, April 11, 1929, at the Stevens Hotel, Chicago, it was moved to dispense with the regular order of business and following the transaction of special business the meeting adjourned to meet at the call of the President.

Approval of Minutes

Minutes of the April 11th meeting of the Board were reviewed and approved.

Report of Executive Secretary

The report of the Executive Secretary was read and on motion duly seconded the report was accepted and ordered placed on file.

Report of Treasurer

The Treasurer's report stated that the books of the Association were audited for the fiscal year ending December 31, 1928, by Robert T. Pritchard, certified public accountant of Chicago, and that this audit, copies of which had been submitted to the Finance Committee, showed the following assets:

Furniture and Fixtures, less Depreciation Reserve.....	\$ 1,143.09
Cash in Bank.....	13,595.15
Accounts Receivable.....	1,327.55
Supplies on Hand.....	1,408.50
Advance rent account 1930 Exhibit.....	500.00

Total	\$17,974.29
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Reserve Fund:

Investments	\$38,079.22
Cash in Bank.....	1,697.75

Total Reserve Fund Assets.....	\$39,758.97
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Award Funds:

Investments	\$21,520.10
Cash in Bank.....	1,619.16
Total Award Fund Assets.....	\$23,139.26

Total Assets	\$80,872.52
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There were no bills payable or outstanding obligations.

The report also included a statement of Income and Expense from January 1 to August 31, giving the total receipts for that period as \$52,090.62, expense \$43,782.70, excess of income over expense \$8,307.92, cash on hand \$15,343.37, and total Reserve Fund assets \$45,914.24.

On motion duly seconded the report was accepted and ordered placed on file.

Philadelphia Research Fund

As a supplementary report the Secretary-Treasurer read a letter from past president G. H. Clamer, General Chairman of the Philadelphia Committee for the A. F. A. Convention in 1928, in which Mr. Clamer advised that at the close of the convention there was an unexpended total of \$2,016.35 in their Entertainment Fund, that letters had been sent to all of the 174 contributors advising the amount of their pro rata balance, and

stating that a refund of the amount would be paid to each subscriber unless said subscriber elected to contribute the amount to the American Foundrymen's Association for a research fund. The letter further stated that 151 responded, advising that they were willing to contribute their pro rata share to A. F. A. and that a check for \$1,819.18 made payable to the A. F. A. was enclosed.

On motion duly seconded the Secretary-Treasurer was instructed to convey to the Chairman of the Philadelphia Committee a vote of thanks of the Board and to deposit the sum of \$1,819.18 in a special savings account to be known as the A. F. A. Philadelphia Research Fund.

Report of Technical Secretary

Technical Secretary R. E. Kennedy stated that he had submitted a written report under date of September 5th to all members of the Board reviewing Association activities for the past year and presenting an outline of proposed activities for the coming year, that he desired now to supplement this by expressing his appreciation to the Board, who had made it possible for him to attend the third International Congress and there to meet those who are directing and taking an active interest in European foundry associations, and further, that he wished to pay tribute to the many active and helpful committee workers, without whose cooperation the work of the technical department would be useless.

On motion the report of the Technical Secretary was accepted and ordered placed on file.

Report of Executive Committee

(No meetings of the committee held since the last Board meeting.)

Report of Manager of Exhibits

C. E. Hoyt, Manager of Exhibits, submitted a report covering the Exhibit held at the Stevens Hotel during Convention week, April 8 to 11, 1929. On motion the report was accepted and ordered placed on file.

Report of Committee on International Relations

H. Cole Estep, Chairman of the Committee on International Relations, briefly reviewed the International Foundrymen's Congress at London and commented on the splendid hospitality of the members of the various branches of the Institute of British Foundrymen whose districts were visited in the two weeks pre-convention tour.

Mr. Estep in commenting on the interval of twelve years between meetings of the International Foundrymen's Congress in the United States, stated that many of our delegation had expressed the hope that arrangements could be made for more frequent meetings in America. After discussion of this question the following resolutions were unanimously adopted:

Whereas the American Foundrymen's Association is anxious to promote the success of the International Foundrymen's Congress, and being particularly desirous of doing everything in its power to foster the utmost interest in these important international events,

Be it Resolved by the Board of Directors of the American Foundrymen's Association, that in its opinion the welfare of the International Congresses would be promoted if they were held in the United States more frequently than at present contemplated;

Be it Further Resolved that the American Foundrymen's Association would be willing to participate in an arrangement with the other interested associations and with the Foundrymen's International Committee whereby the International Congresses could be held in the United States once every nine years, the next such congress in the United States to be in 1935;

Be It Further Resolved that the Committee on International Relations of the A. F. A. is hereby instructed to convey to the Foundrymen's International Committee and the appropriate other persons and organizations abroad the intent of this resolution for the purpose of instituting negotiations leading to an arrangement whereby the International Foundrymen's Congresses may be held in the United States every nine years as set forth herein.

On motion the Executive Secretary was instructed to extend an official invitation from the Board to Mr. Wesley Lambert, President of the I. B. F., to attend the 1930 convention of the A. F. A.

On motion the Secretary was also instructed to extend an official invitation to the presidents of all European foundry associations represented on the Foundrymen's International Committee to attend the 1930 convention of the A. F. A.

Report of Committee on Room Entertainment

The Chair called for the report of the Committee on Question of Room Entertainment, consisting of S. C. Vessy, Chairman, B. H. Johnson and P. J. Krentz. Mr. Vessy reported that the committee had received a copy of the letter the Secretary had written to the members of the Foundry Equipment Manufacturers' Association, also a copy of action taken and resolutions adopted by the F. E. M. A. strongly condemning the practice and pledging cooperation with the Board of Directors in any action taken to abate it.

Following discussion it was moved that the matter be recommended to the new Board for action and that the committee be requested to prepare resolutions for adoption. Motion seconded and carried.

Report of Committee on Revisions to By-Laws

The report of the Committee on Revisions to By-Laws, consisting of E. H. Ballard, A. B. Root, Jr., and A. E. Hageboeck, was called for and presented by the Chairman, Mr. Ballard.

"The committee appointed to consider proposed changes in the By-Laws begs leave to submit the following report:

"The committee approves for your consideration the following revisions of the By-Laws, copies of which were submitted to all Directors with the Executive Secretary's letter of August 27th:

AMENDMENTS TO BY-LAWS

ARTICLE I (No change)

ARTICLE II

Membership

Section 1.—The membership of this Association shall consist of the following classes: Firm, Individual, Affiliated, Associate and Honorary.

Section 2.—Firm Membership. Firms, companies, corporations or owners interested in the objects of this Association may be elected firm members. The membership privileges of a firm shall be exercised by a designated individual.

Section 3.—Individual Membership. Any person interested in the objects of this Association may be elected an individual member.

Section 4.—Affiliated Membership. Any person affiliated with an organization holding firm membership may be elected an affiliated member.

Section 5.—Associate Membership. Any person actively engaged in educational or research pursuits relating to the foundry industry, not of a commercial character, may be elected an associate member.

Section 6.—Honorary Membership. Any person whose activities in the Foundry Industry, or any branch thereof, or whose services in connection with the objects of this Association make him preeminent among his fellows, may be elected to Honorary Membership.

Section 7.—Election to Firm, Individual, Affiliated and Associate Membership shall be by a three-fourth vote of all the Directors. All applications for membership shall be made in writing to the Executive Secretary, by whom they shall be referred to the Directors.

Section 8.—Same as present Section 6.

Section 9.—All members shall enjoy equal privileges, have the right to vote and to hold office.

Section 10.—Same as present Section 8.

Section 11.—Same as present Section 9.

ARTICLE III

Officers and Directors

Sections 1 and 2.—No change.

Section 3.—A President and a Vice-President shall be elected annually to serve for one year, or until their successors are elected and qualified.

Five Directors shall be elected annually to serve for a term of three years, or until their successors are elected and qualified.

Sections 4 and 5.—No change.

ARTICLES IV, V, VI and VII (No change)

ARTICLE VIII

Dues

Section 1.—Dues for Firm Members residing in the United States and Canada shall be \$25.00 per annum.

Dues for Firm Members residing in all other countries shall be \$15.00 per annum.

Dues for Individual Members residing in the United States and Canada shall be \$15.00 per annum.

Dues for Individual Members residing in all other countries shall be \$10.00 per annum.

Dues for all Affiliated Members shall be \$7.50 per annum.

Dues for all Associate Members shall be \$5.00 per annum.

Honorary Members shall not be required to pay dues.

All dues shall be payable in advance on the first day of January of each year. Any member whose dues are twelve months in arrears shall be declared delinquent and shall be dropped from the membership roll.

In recognition of long or special service, or for other justifiable reasons, the Board of Directors may, by a three-fourth vote, exempt any member from payment of dues and declare him a member for life.

Section 2. Dues of newly elected members may be prorated during the first year in accordance with rulings established by the Board of Directors and shall be payable upon notification of election.

ARTICLES IX, X, XI, XII, XIII, XIV (No change)

ARTICLE XV

Publications

Section 1.—The Board of Directors shall have the power to determine the form and method of distribution of the publications of the Association.

ARTICLES XVI, XVII and XVIII (No change)

Following presentation of the report Mr. Ballard moved that the revisions be approved and referred to the incoming Board for action. Motion seconded by Mr. Utley and carried.

Report of Election of Officers and Directors

The Secretary reported that at the annual business meeting of the Association held at the Stevens Hotel Monday, April 8, 1929, the following Officers and Directors were declared elected, to assume office following adjournment of the annual meeting of the present Board:

For President to serve for one year:

Fred Erb, President, Erb-Joyce Foundry Co., Detroit, Mich.

For Vice-President to serve for one year:

N. K. B. Patch, Secretary, Lumen Bearing Co., Buffalo, N. Y.

For Directors to serve three-year terms each:

Harold S. Falk, Vice-President and Works Manager, Falk Corp., Milwaukee, Wis.

S. T. Johnston, Vice-President, S. Obermayer Co., Chicago, Ill.

Frank J. Lanahan, President, Fort Pitt Malleable Iron Co., Pittsburgh, Pa.

Arnold Lenz, Manager, Chevrolet Motor Co., Saginaw, Mich.

Delos H. Wray, Vice-President, Henry Wray & Son, Inc., Rochester, N. Y.

Appreciation

The Secretary stated that when this meeting adjourns, the terms of office of three Directors will expire. A. B. Root, Jr., first elected a Director in 1919, had with the exception of the year 1921 served continuously as a member of the Board, either as a Director, Vice-President or President, while Martin W. Henley, S. C. Vessy, and L. C. Wilson would complete three year terms as Directors.

Mr. Johnston moved that a vote of appreciation be given to these gentlemen, and particularly to Mr. Root, who had served so long and faithfully in advancing the welfare of the Association. Motion seconded by Mr. Utley and carried.

President Johnston announced that if there was no further business to be transacted, he would take this opportunity of expressing appreciation and thanks to all Officers and Directors for their helpful cooperation during his term of office, that he was deeply appreciative of the opportunity and privilege of having served the American Foundrymen's Association as its twenty-seventh President and that he would now turn the gavel and the meeting over to Mr. Fred Erb, his successor.

President Erb in accepting the gavel expressed appreciation of his election to the high office of President of the A. F. A., briefly outlined what he hoped would be accomplished during his term, and then announced that he would entertain a motion for the final adjournment of the present Board, immediately following which the new Board would convene.

On motion duly seconded the meeting stood adjourned.

Respectfully submitted,

C. E. HOYT, Executive Secretary.

Approved: S. T. JOHNSTON, President.

Minutes of First Meeting, 1929-30 Board of Directors

AMERICAN FOUNDRYMEN'S ASSOCIATION

STATLER HOTEL, CLEVELAND, SEPTEMBER 12, 1929

President Fred Erb presiding.

Roll Call

The following Officers and Directors responded to roll call: President Fred Erb, Vice-President N. K. B. Patch and Directors E. H. Ballard, H. Y. Carson, H. Cole Estep, A. E. Hageboeck, C. E. Hoyt, B. H. Johnston, P. J. Krentz, L. W. Olson, S. W. Utley, S. T. Johnston, Frank J. Lanahan and Arnold Lenz. Absent, Wm. J. Nugent, Harold S. Falk and Delos H. Wray.

Others present were Past Directors A. B. Root, Jr., and S. C. Vessy, Technical Secretary R. E. Kennedy and Past Presidents L. L. Anthes and B. D. Fuller.

Organization of New Board

The Chair announced that the Board would proceed to organize by the election of Officers and four members of the Executive Committee, in accordance with the provisions of the By-Laws, and that he would appoint Messrs. S. T. Johnston, P. J. Krentz and H. Y. Carson members of the Nominating Committee.

Luncheon

After the Nominating Committee had been appointed, the Chair declared there would be a recess for luncheon, at which the members of the Board would be the guests of Mr. Howard Dugan, Manager of the Statler Hotel. Past President Major R. A. Bull joined the Board for luncheon.

After lunch President Erb announced that following the usual custom he would call upon those present for a report on business conditions in their respective districts and industries. Mr. Eugene J. Ash was then called upon to give a report of the work he was doing at the Bureau of Standards for the A. F. A. Committee on Cast Iron in developing methods for determining the liquid shrinkage of metals.

Second Session

At 2:15 the Board reassembled in the meeting room and the Chair called for a report of the Nominating Committee. Mr. S. T. Johnston, Chairman, reported as follows:

First, the committee recommends that the offices of Executive Secretary, Treasurer and Manager of Exhibits be combined in one, as provided for in Section 1, Article III of the By-Laws.

On motion duly seconded the recommendation of the committee was approved and Mr. Johnston proceeded with his report.

Second, for the combined office of Executive Secretary, Treasurer and Manager of Exhibits we nominate C. E. Hoyt.

Third, for the office of Technical Secretary we nominate Robert E. Kennedy.

Fourth, for four members of the Executive Committee to serve with the President, Vice-President and Executive Secretary we nominate S. W. Utley, B. H. Johnson, Frank J. Lanahan and, according to established precedent, the retiring President, S. T. Johnston.

Mr. Olson moved that the report of the Nominating Committee be accepted and that the Chair cast the unanimous ballot of the Board for the candidates nominated. Motion duly seconded and carried, whereupon the Chair announced that he would cast the unanimous ballot of the Board for C. E. Hoyt for Executive Secretary, Treasurer and Manager of Exhibits, R. E. Kennedy for Technical Secretary, and S. W. Utley, B. H. Johnson, Frank J. Lanahan and S. T. Johnston for members of the Executive Committee.

Report of Finance Committee

The Chair announced that the Finance Committee was composed of the immediate Past President, the President and the Vice-President, the Vice-President acting as Chairman, and called upon Vice-President Patch for a report and recommendations on salaries for the ensuing year. Mr.

Patch stated that the Board had received the report of the Treasurer, that they had no further report to make on Association finances at this time, and would make the following salary recommendations:

That the combined salary of C. E. Hoyt as Executive Secretary, Treasurer and Manager of Exhibits be \$12,000, the same as for the past year.

That the salary of R. E. Kennedy, Technical Secretary, be \$6,600, an increase of \$600, beginning October 1, 1929.

The committee also recommends that Miss Jennie Reininga be elected Assistant Secretary-Treasurer and that her salary be \$300 per month, beginning October 1, 1929.

Mr. Carson moved that the report and recommendations of the Finance Committee be approved. Motion duly seconded and carried.

Disbursement of Funds Resolutions

The Chair then called for the customary resolutions on disbursement of funds, which were read by the Secretary.

Resolved, that checks for the withdrawal of funds deposited in the name of the Association in the Harris Trust & Savings Bank, Chicago, shall bear two signatures as follows: President Fred Erb and Executive Secretary-Treasurer C. E. Hoyt, or Vice-President N. K. B. Patch and Executive Secretary-Treasurer C. E. Hoyt, or President Fred Erb and Vice-President N. K. B. Patch.

Be It Further Resolved, that the resolutions required by the aforesaid mentioned bank authorizing the withdrawal of funds of the Association, in accordance with the above resolution, are hereby approved and adopted.

Be It Further Resolved, that the officers of the Association are hereby authorized to open an account in the convention city for a special convention fund, they to determine how this account shall be opened and the signatures required for the withdrawal of said fund.

Bt It Further Resolved, that the Board authorize a Secretary-Manager's petty cash fund of \$1,000, said fund to be reconciled at the end of each month by a full statement of expenditures.

Be It Further Resolved, that the President and Executive Secretary are authorized to employ such assistance as is found necessary to take care of Association activities, compensation for such services to be approved by the Finance Committee.

Mr. Utley moved that the resolutions be adopted as read. Motion duly seconded and carried.

Treasurer's Bond

Resolved, that in accordance with provisions of the By-Laws, the Treasurer shall be required to give a bond to the amount of \$5,000, the premium on said bond to be paid by the Association.

On motion duly seconded the above resolution was approved.

Auditing of Books

Resolved, that the President be authorized to engage an auditor to audit the books for the year ending December 31, 1929.

On motion duly seconded the resolution was approved.

Committee Appointments

Resolved, that the President be authorized to make all appointments for standing and special committees that are not provided for in the By-Laws or by special act of the Board.

On motion duly seconded the resolution was approved.

Resolution Authorizing Payment of Committee Meeting Expenses

Resolved, that the Secretary-Treasurer be authorized to reimburse Directors and committee members for traveling expenses to any regularly called Board or committee meetings, except such meetings as are held at the place and during the week of the annual convention of the Association when, unless specially authorized, no expenses will be paid.

Be It Further Resolved, that in the instance of joint committee meetings being held, the Secretary-Treasurer be authorized to pay an equitable proportion of the traveling expenses incurred by committee members.

On motion duly seconded the above resolutions were approved.

Resolution Covering Authority of the Executive Committee

Resolved, that the Executive Committee be empowered to act for the Board in the interim between Board meetings on all matters requiring Board action.

On motion duly seconded the resolution was approved.

Letter Ballot on Revision of By-Laws

On motion duly seconded the Executive Secretary was instructed to prepare a letter ballot to be submitted to the membership for their approval of the revisions to the By-Laws unanimously approved by the Board of Directors at a meeting of the old Board held this date.

Secretary Hoyt moved that if the amendments to the By-Laws were approved by letter ballot of the members, that the new classifications and rate of dues take effect immediately after January 1, 1930, for all members elected after ratification, and that they not become effective until January 1, 1931, for members of record at date of ratification of changes.

Resolutions of Room Entertainment

Mr. Vessy, Chairman of the committee, who had been instructed at the previous meeting to prepare resolutions on room entertainment, submitted the following:

Whereas, the practice of lavish, unwarranted and wholesale entertainment in hotel rooms and elsewhere is being indulged in by certain exhibitors and others attending conventions of the American Foundrymen's

Association, resulting in conditions inimical to the best interests of said Association, and

Whereas, such practices detract from and tend to defeat the purposes of such conventions, reflect discredit on the men of the industry, and discourage companies from sending their representatives to such conventions, and

Whereas, such practices result in excessive, unnecessary and unwarranted expense, contrary to good business ethics and practices,

Now Therefore Be It Resolved, by the Board of Directors of the American Foundrymen's Association, at the annual meeting held in the city of Cleveland, Ohio, September 12, 1929, that exhibitors and all other interests concerned be requested to cooperate in the abatement of such practices, and that the Manager of Exhibits and the committee on convention arrangements be and they hereby are authorized and directed to take such action as in their judgment may be expedient or necessary to abate such practices.

On motion by Mr. Utey, seconded by Mr. Olson, the resolutions were unanimously approved.

The Secretary announced that a copy of his letter of August 26th, together with a copy of action taken and resolutions adopted by the F. E. M. A., had been mailed to the managers of all leading hotels in Cleveland and an invitation extended to them to attend the Board meeting to discuss this subject, and that Mr. Dugan, Manager of Hotel Statler, Mr. Pierce, Manager of Hotel Cleveland, Mr. Koontz, Manager of Hotel Winton, and Mr. Hogeran, Assistant Manager of the Hollenden Hotel, were waiting outside. The above named gentlemen were requested to come into the meeting and were introduced to the members of the Board.

The resolutions adopted were read to them and their reactions requested. Mr. Pierce of Hotel Cleveland, who spoke first, said:

"I do not know that I am authorized to be the spokesman for the entire group. There may be a complete divergency of opinion on this. I have my own views and concur with you most heartily. I think you have taken a big step forward in the conduct of conventions and it will mean a great deal to all national societies. I speak from what I believe is thoroughly authentic information on this.

"This is a condition which all of us have known existed. We have treated it as a necessary evil. I do not think it is altogether necessary. For my own part I am very, very much delighted to know that an association of the importance of your own has taken this action. I think it will have a far reaching and wholesome effect not only on your own convention, but conventions in general.

"I happen to have attended a meeting last summer of business and promotion managers representing the largest hotels and hotel chains throughout the country, at which this was a topic for very serious discussion and consideration. It could not be discussed on the floor for obvious reasons, but it was discussed in committee meetings and given very serious con-

sideration. I am sure all those men would have left Toronto much happier if they had been able to look forward and know that a society of the prominence of your own was going to take the action you have taken this afternoon."

Mr. Koontz, Hotel Winton: "Gentlemen: There is very little I can add to what Mr. Pierce has already said. I know it is the general consensus of opinion of all the large hotels here in Cleveland that they welcome this action on your part."

Mr. Dugan, Hotel Statler: "You will find the Statler Hotels will cooperate. In mentioning the evils to the hotel, I think one evil was overlooked and that is the disturbance to the man who is not with a convention but is next to a room in which convention delegates are celebrating. He goes away with a very bad opinion of the hotel and expresses it to his friends. We in the Statler are heartily in accord and will cooperate in every way."

Mr. Hogeran of the Hollenden Hotel, speaking for the Manager, Mr. DeWitt, said that they heartily endorsed all that had been said by the other gentlemen and could assure us of the hearty cooperation of the management of the Hollenden.

Mr. Pierce: "If I might be permitted to add one statement which may be of interest to you, although I dare say you have included it in your discussion before, it has long been my impression that this wholesale entertainment is not entirely voluntary, but is something that has accrued and pyramided and people are being forced into it.

"I never had that more forcibly thrust home to me than during two or three conversations yesterday. It was clearly evident that entertainment has reached the competitive stage, where firms are being forced to do it reluctantly, knowing that it entails a lot of expense and nuisance. They would gladly cease if they were sure their competitors would do the same."

Publication of Transactions Monthly

President Erb called the attention of the Board to the Executive Secretary's letter of August 14th on the subject of publications, in which it was proposed that the Transactions be published monthly. The Chair stated that the whole question of A. F. A. publications had been discussed at length in this and later communications and asked for comment.

The Secretary read a supplementary report, which had been dictated after considering replies received from Directors and his own further reactions to proposals made. He stated that so far as he could learn, the name for the monthly publication, "Transactions of the American Foundrymen's Association," was acceptable, as was the proposed date of issue, the 15th of each month.

He stated that the question had been raised as to the possibility of developing a worth while section for reporting activities of local foundry associations and offered suggestions as to how this might be worked up. He believed that the monthly publication would be a very helpful medium

for carrying out the program of the Committee on Castings Promotion, that the abstracts of foundry literature could be continued and broadened, and that he did not believe it would be advisable to have a department for publishing patents issued.

On the subject of advertising, the Secretary said that in proposing a monthly publication they had not counted on receipts from advertising to support it, and he would recommend that for the first year, at least, the monthly publication be carried on without commercial advertising.

The question was called for and on motion it was voted that the Transactions of the American Foundrymen's Association be made available to members through the medium of a monthly publication, beginning January, 1930, and that the annual bound volume of Transactions be made available to members who subscribe for it at the approximate cost of binding, the price to be determined annually. Motion duly seconded and carried.

Additional Staff

The Secretary called attention to his letter to the Directors of August 17th, stating that if it was voted to publish the Transactions monthly, it would be necessary to add immediately to our staff someone to assist in getting it out.

Mr. Olson moved that the recommendation be approved and that the Secretary be authorized to engage such a man. Motion duly seconded and carried.

Advertising

The question was again raised of commercial advertising in the monthly publication containing the Transactions. It was the consensus of opinion that advertising should not be included and Mr. Lenz so moved. Motion duly seconded and carried.

1930 Technical Program

The recommendations contained in the report submitted by Technical Secretary Kennedy under date of September 5th outlining program for the 1930 convention were discussed. They were quite generally approved, but no action was taken.

Divisional Activities Correlation Committee

Mr. Patch, Chairman of the Divisional Activities Correlation Committee, reported a meeting of the committee held in Cleveland the previous day.

Mr. Hoyt moved that the report be accepted and the committee continued, with the recommendation that some definite plan of divisional organization be later submitted to the Board for consideration. Motion duly seconded and carried.

Research Appropriations

Mr. Kennedy reported that the Executive Committee of the Committee on Molding Sand Research had approved a request of the Committee on

tests for an appropriation of \$1,200.00 for the continuation of the work on evaluating clay bond properties.

The Executive Committee also recommended an appropriation of \$250.00 for the preparation and supply of standard sand for the use of the Subcommittee on Core Tests.

Mr. Hoyt moved that the above appropriations, totaling \$1,450.00, be authorized. Motion seconded by Mr. Patch and carried.

Appropriations for Prizes

Mr. Hoyt moved that the Board of Directors authorize the offering of prizes for best papers and apprentice molding and pattern making contests at the 1930 convention, the prizes to be of the same value as offered in 1929, provided the Board of Awards vote the necessary funds for said prizes. Motion duly seconded and carried.

Entertainment at Cleveland Convention

A general discussion was held on the kind of entertainment to be provided at the Cleveland Convention and method of financing. It was moved that the question be referred to the Committee on Convention and Exhibits, with power to act. Motion duly seconded and carried.

Nominating Committee

It was moved that the Chair appoint a Nominating Committee of three Directors to canvass the names proposed and select a ticket for the election by letter ballot of the members of four members and four alternate members of the 1930 Nominating Committee. Motion duly seconded and carried.

The Chair announced that he would appoint as members of the committee Directors S. T. Johnston, H. Cole Estep and S. W. Utley.

Honorary Membership

Mr. Utley stated that it is customary for the Board to propose to the membership that the retiring President be elected to Honorary Membership and it gave him great pleasure to propose, therefore, that the Board recommend the name of Past President S. T. Johnston for Honorary Membership. Motion duly seconded and carried.

1931 Convention

It was moved that the Committee on Convention and Exhibits to be appointed by President Erb be empowered to investigate and make recommendations to the Board as to time, place and character of the 1931 Convention and Exhibit. Motion duly seconded and carried.

Past President L. L. Anthes of Toronto invited consideration of Toronto as a place for holding the 1931 convention.

Mr. H. Y. Carson likewise invited consideration of Birmingham as a place for holding the 1931 convention and exhibit, stressing the importance

of the A. F. A. giving encouragement and aid in the development of the foundry industry in the south.

Movies of International Foundrymen's Congress

The Secretary announced that several of the delegates to the International Foundrymen's Congress had brought their movie films with them and that arrangements had been made to show these in the Lattice Room of the hotel at 8:00 P. M.

Mr. Patch moved that a vote of thanks be given the management of the Statler Hotel for their splendid hospitality and cooperation in connection with this meeting. Motion duly seconded and carried.

On motion duly seconded the meeting stood adjourned.

Respectfully submitted,

C. E. HOYT, Executive Secretary.

Approved: FRED ERB, President.

Following adjournment, the committee appointed to prepare a ticket for the election of four members and four alternate members of the Nominating Committee met and selected the following ticket:

T. H. Addie, President, American Manganese Bronze Co., Holmesburg, Philadelphia, Pa.

Robert E. Bryant, Vice-President, Jefferson Union Co., Lockport, N. Y.

R. J. Doty, Plant Manager, Reading Steel Casting Co., Reading, Pa.

M. J. Evans, Vice-President, Whiting Corp., Harvey, Ill.

James W. Gibney, President, Bingham & Taylor Corp., Buffalo, N. Y.

Wm. J. Grede, President, Liberty Foundry, Inc., Wauwatosa, Milwaukee, Wis.

H. B. Hanley, American Laundry Machinery Co., Rochester, N. Y.

Fred Kirby, General Supt., John Deere Spreader Works, Moline, Ill.

E. F. Stockwell, Barbour-Stockwell Co., Cambridge, Mass.

J. L. Wick, Jr., President, Falcon Bronze Co., Youngstown, Ohio.

The Secretary was instructed to have the ticket printed and mailed to all members, after first securing the consent of members named to having their names appear on the ballot.

Why We Train Apprentices

BY J. A. DAVIES,* PHILADELPHIA, PA.

In opening a discussion on the subject of why we train apprentices, it should be borne in mind that I speak only from an experience of the past ten years in the Philadelphia district. Furthermore, my remarks are qualified by the fact that I speak as one having experience with what is to all intents and purposes a large jobbing foundry where none of the advantages of quantity production are to be found, and all of the work is of a high grade type with close tolerances on dimensions and weight. At no time during those years have we been able to hire sufficient foundry mechanics, particularly experienced molders and core-makers.

It may be that there are parts of these United States where an ample supply of skilled mechanics can be obtained without particular trouble. Such is not the case in the territory from which I come. Even if it were, I am sure that we would have a more satisfied feeling, knowing that as an organization we were contributing to the training of this important class of workers, instead of reaping the benefits of the efforts of others without any effort on our part.

That there should be more discussion on the subject of apprentices in the foundry than there is in the other branches of the metal working industry is at first sight difficult to appreciate, and yet the fact is true that the average foundryman of the past two decades has been hard to convince regarding the

*General Superintendent, Westinghouse Electric and Manufacturing Co., South Philadelphia Works.

need, not only for training apprentices, but for training a different kind of apprentice and training him in a different way.

It is not so long since that the jocular expression "the foundry is no place for a man with brains" was a common one and contained a modicum of serious belief. As a matter of fact, not longer than six years ago a foundryman of considerable experience told me in all seriousness that a technical graduate was unwelcome in the foundry and would be wasting his time.

We who are interested in the foundry and appreciate not only the possibility for its product but also realize the effect of the rapid adoption of substitutes, understand the need for well trained men in our foundries if they are to maintain themselves as the largest contributors of material to the machinery builders' art.

It is with no thought of speaking disrespectfully of the many fine and hard working men who have done so much in years gone by to make outstanding contributions to the foundry art, when I say that the general method by which many of them received their practical training must, by the force of modern circumstances, undergo changes. The acquiring of foundry knowledge by "rule of thumb" methods must go, as it has had to go in all other progressive industries. Until a very few years ago, engineers and schools of higher engineering learning devoted practically all of their skill to the advancement of engineering design and, to a lesser degree, machine shop practice, but largely neglected the foundry. For that reason, foundries have been struggling against heavy odds, until they are, or were recently, standing with their backs to the wall.

For a while, it seemed as though designing engineers, in their endeavor to obtain lighter weights, lower costs and quicker deliveries, were doing their best to eliminate castings from machine designs wherever it was practicable to use a substitute construction.

Who has not heard these designers complain that when their drawings call for a casting 1 inch thick, the foundry is most likely to turn out a piece from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches thick?

What seemingly endless talk occurs between the foundry and the machine shop on the subjects of hard iron that won't machine easily, open grain that looks bad, burnt in sand, etc.?

How often have the assembling shops complained that too much backing has been put on the flanges so that the spotfacing buries the nuts, and extra machine work and additional hand labor in the form of chipping become necessary before the part can be shipped?

Think, too, of the explaining that has to be done to the customer's inspector to get him to agree to the use of a patch over a spongy and leaky part of the casting.

As long as engineers found it necessary to use castings, insufficient heed was given to their complaints. But now, the availability to the designer of adequate substitutes for many castings has forced the foundrymen to realize that a great advance must take place in their industry; uncertainties must be replaced by certainties; facts must be ascertained and a course of logical procedure laid out based upon those facts.

I think you will agree with me that the most important element in this situation is that of adequate training for the foundry personnel. Little good would it do to put in the most modern sand handling equipment, the finest cupolas, the most up-to-date methods for cleaning castings and all of the other advantages so rapidly becoming available, unless the people directing these many activities are not only in sympathy with them, but are equipped mentally to appreciate their significance, and to utilize them to the limit of the possibilities.

If we agree on this in principle, I feel the caption "Why We Train Apprentices" is more than half explained. I well remember the day when an apprentice in the foundry was an exception rather than the rule. The customary practice in the district where I worked for many years was to bring into the foundry as a molder's helper a muscular individual, often speaking broken English, and none too well equipped mentally, largely due to his schooling having ceased at a low grade. By association with the other men in the foundry, he became familiar with the work and in due course was made a rammer. Later on, and particularly when a business boom occurred and molders were hard to get, he was given simple molding operations to do, finally working up to the point where he was rated as a regular molder.

Such men, and there were many of them in the past twenty-five years, were greatly handicapped by their lack of education

and training. They found it difficult because of that fact to diagnose accurately the troubles they encountered, and, unaided to a considerable degree by any of the scientific work that was being so freely given to designing and machining, they had to resort to a trial and error method in overcoming the more obscure cases.

Keeness of competition and the insistent demand for better product at lower prices has forced to the front the need for the utmost in the way of skill in our foundry work. We are training apprentices for the sole purpose of getting into our foundry force young and virile men with alert brains, who have been taught to reason cause and effect and to apply the common rules of science that have so largely contributed to the success of other branches of industry. These young men are being carefully watched and their progress in the trade followed so that we have a record of men who possess the qualifications of supervisors. We are giving preference to high school graduates with the thought that their larger store of knowledge, particularly in mathematics and English, will enable them more readily to deduce facts and then put them into clear expression. We are not satisfied to sit supinely back and let welded steel products and other substitutes take the place that should be occupied by sound foundry work. To do this with success we realize full well that we must train our future foundrymen to the limit of our ability. If we do this, we have every assurance that in the march of progress, rapid though it be, foundry work will be found well up in the van of the mechanical trades, with products that are dependable, accurate, and a source not only of profit but of pride as well, to manufacturer and owner alike.

How We Train Apprentices

BY A. M. CORNELL,* CHICAGO, ILL.

About five years ago we decided to train apprentices and, although today we are still novices as compared with foundrymen in some other sections of the country, particularly our friends in Milwaukee, we have been quite successful in our undertaking. At any event, we must have established a reputation, as the Chairman of the A. F. A. Committee on Apprentice Training has requested us to prepare a paper on "How We Train Apprentices."

All concerns should be vitally interested in apprenticeship from an economical standpoint as desirable employes, particularly for foundries, are becoming increasingly difficult to secure.

The immigration law reducing the quota of immigrants has made it essential that we interest our own American boys. The easy "white-collared" jobs attract them unless we are able to demonstrate the value of learning a trade. Training the youth of today to be good citizens of tomorrow is necessary if our country and our shops maintain their high standard of efficiency and their lead in foreign competition.

Further, it is advantageous to us as manufacturers to build up our organizations with good, reliable, trained and intelligent workmen. We must have these trained mechanics if we are to be supplied with future foundry executives.

The proposition is mutually advantageous as both the apprentice and the manufacturer profit; the apprentice by the experience he obtains and the trade that he learns, and the manufacturer economically, inasmuch as he has found that the apprentice pays his own way.

In preparing an apprentice program it is necessary to consider: product, equipment, size of plant and location of plant in reference to other shops and schools.

*Vice-President, Pettibone Mulliken Co.

A successful training program requires the interest and earnest co-operation of all plant executives. We have taken tentative programs submitted by our department heads and from them prepared the program and schedules now in use, which include time required in each sub-department, school, subjects, talks and rates of pay.

The following covers our foundry apprentice course, and our tool room and pattern shops are generally similar.

Employment

1. Entrance Requirement.

Application for enrollment in the Student Training Course of Pettibone Mulliken Company must be made in person. Applicants must not be less than 17 years of age and must prove themselves to the company's satisfaction to be honest boys of good behavior, physically sound, and of good moral character.

2. Contact and Publicity Maintained in the Community.

It is well to take every opportunity possible to advertise the student training courses. We have done so. This includes talks to high school students, parent-teacher associations, articles in community papers, tours through other plants, and the entrance of students in trade competitions, such as the American Foundry Association has held for apprentices in the past. Our booklet entitled "Story of the Trades" is in the hands of vocational advisors in the high schools and universities in Chicago and elsewhere.

3. Sources from Which Apprentices Are Obtained

We have secured high class students from schools, by recommendation of employes and the apprentices themselves, and through the department heads and executives of the shop, and even salesmen of companies who supply our foundry with material.

PETTIBONE MULLIKEN CO.**4710 W. DIVISION STREET****EMPLOYMENT DEPARTMENT**

Questionnaire to be filled out by guardian of Student Applicant
 Date 19....
 Full Name of Guardian.....
 Home Address.....
 Relationship of Guardian.....
 Occupation
 Business Address.....
 Are you in favor of having applicant learn the.....
 trade?.....
 Should student applicant be accepted by us as a student in the
 trade, will you together with student execute a
 contract which will be for a period of years?
 We are desirous of obtaining students of serious mind only,
 who are industrious and who have the ambition and determina-
 tion to continue their full term of apprenticeship so that they
 may learn the trade as it should be learned, in
 order that they will be a credit not only to themselves and to
 their parents, but to their country as well.
 We should be glad at any time to have you as our guest
 so that we could go into detail on the outline of course, school,
 personnel of our organization, and plant.
 Yours sincerely,

 EMPLOYMENT MANAGER.
 "Pettibone Mulliken Company Is a Good Place to Work"

FIG. 1—QUESTIONNAIRE FILLED OUT BY PARENT OR GUARDIAN

4. Method of Selection.

When a boy applies for a position as a student worker he is questioned as to the trade in which he is most interested. As it is rather hard at times for the boy to know exactly what trade he should follow, due to the fact that he has had a variety of several kinds of shop work such as is offered in all technical schools, the interviewer, naturally, plays a very important part. The interviewer, therefore, must devote the necessary time to ascertain the subjects the boy was most interested in while attending school. From these inquiries we have been able to assist the boy in determining the trade for which he is best adapted. In the majority of cases the interviewer aids the boy to "find himself."

Our Director of Personnel, who has charge of our training program, has adopted a plan of self analysis which, by the way, has proved 90 per cent successful. Should a boy apply for position as student worker in our tool room and not be interested in

PETTIBONE MULLIKEN CO.

OFFICE:
725 MARQUETTE BUILDING

CHICAGO,

Dear Sir:

Getting honorable, serious minded and industrious boys in our organization as "student workers" so that they may become efficient and skilled workmen is our problem.

You realize, as well as we do, that it takes time and study to get to know a boy. It is difficult to get boys who will be interested during the whole training period, and who will make worthwhile tradesmen. Therefore, you know how sincerely we will appreciate your filling out the blank below, which we will keep **STRICTLY CONFIDENTIAL**.

This is for the good of the **STUDENT** and the **TRADE**.

.....
has applied to enter our **STUDENT TRAINING COURSE** as

..... attended the school
from to While there his gen-
eral record was, and especially in
was, and in was

He (was or was not interested) in his school work: he was
interested outside of class in.....

His teacher's opinion of him is.....

.....

Signed.....

Any added information or opinion, which as principal you
may have, will be appreciated.....

.....

Principal.....

Cordially yours,
PETTIBONE MULLIKEN CO.
Employment Manager

FIG. 2.—LETTER REQUESTING INFORMATION ABOUT PROSPECTIVE
APPRENTICE

mathematics or mechanical drawing it would be logical to assume that he would be unsuccessful in following the tool making trade. Obviously, if the boy desired a clean "white-collared" job he probably would not become an enthusiastic foundryman. The interviewer must take all these matters under advisement because the boy's future depends upon the assistance he is given and the analysis made.

When the department for which the boy is most fitted has been determined he is shown this department and the balance of the shop, and the good features as well as the bad thoroughly explained to him. We next send a questionnaire (Fig. 1) to his

parent or guardian and request that the same be filled out. The boy is given a book entitled "The Story of the Trades" and told to return. In the meantime another questionnaire (Fig. 2) is sent to the principal of the school last attended by the boy for further information relative to his school record. When the applicant returns, preferably accompanied by parent or guardian, he is given a second interview to ascertain if he still desires to follow the trade suggested at the first meeting, and at the same time the importance of completing his term is stressed. An appointment is made for a later date at which time he is hired providing he passes the physical examination and is approved by the Board of Governors, which consists of our Works Manager and Director of Personnel. The selection of all our apprentices is only by the approval of the Board of Governors, and the discharging can only be by sanction of the same board.

How Apprentices Are Introduced to the Shop

1. Instructions.

The Director of Personnel introduces the apprentice to the superintendent and foreman. The superintendent then welcomes the boy to his department, tells him the importance of complying with safety and other rules, talks to him relative to quality and workmanship, and the importance of completing his course, and further impresses upon him the fact that he wants him to learn his trade as it should properly be learned. Our graduate apprentices should be a credit to our company and we have made them so. The apprentice is also told to keep his eyes open and to ask questions.

2. The Kind of Work to Which First Assigned

In our Foundry Course the first task assigned to the apprentice is clerical work. This he does for three weeks and we have found it to be a splendid plan as the apprentice then becomes acquainted with our method of orders and time cards, and it further offers him an opportunity to acquaint himself with location of departments, supplies, and the general plan of our shop.

Probationary Period

1. Length of Period.

When an applicant has been accepted and commences work, he is placed on probation for a period of from three to six months, and if at the expiration of that time he has satisfactorily demonstrated to the employer that he possesses the necessary ability and other qualifications to make him a successful student at his chosen trade, he and his parent or guardian execute the

STUDENT SHOP RECORD

NAME John Doe CLOCK NO. 1642 MONTH November YEAR 1927

NAME OF MACHINE OR WORK	DAYS OF MONTH																															MONTHLY TOTAL OF HOURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
<u>Iron Mould</u>	9	9	2															9														95 1/2
<u>Core Room</u>																																67
<u>School</u>																																2
DAILY TOTAL HOURS																																166 1/2

BOARD OF GOVERNORS { MONTHLY GRADE _____
REMARKS _____
FOREMAN _____

FIG. 3—SHOP RECORD FOR MONTH'S PERIOD

student Mechanic's Course Agreement of the Pettibone, Mulliken Company.

2. The Kind of Work Done During the Probationary Period.

During his probationary period the apprentice is assigned to clerical and then core room work. It has been our experience that an apprentice serving successfully in these two departments usually completes his apprenticeship.

3. Approval of Probationary Period.

The Board of Governors, together with the Foundry Superintendent, the Student's Foreman, and the School Instructor, determine at the end of the probationary period whether or not the student has been successful and should be retained. Occasionally the probationary period is extended another three months. We have found this probationary period to be very important as some students learn quickly and others do not. Injustice can

101 1-1-14

STUDENT SHOP RECORD

NAME John Doe CLOCK NO. 1644 MONTH Master Card YEAR 1897-98

NAME OF MACHINE OR WORK	DAYS OF MONTH																															MONTHLY TOTAL OF HOURS		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31			
Grinding																																	Total Hours for Month	152 7/8
Small Casts																																	Total Hours for Month	152 7/8
Jacks																																	Total Hours for Month	152 7/8
Corse																																	Total Hours for Month	152 7/8
Mach.																																	Total Hours for Month	152 7/8
Mould.																																	Total Hours for Month	152 7/8
Beach																																	Total Hours for Month	152 7/8
Mould.																																	Total Hours for Month	152 7/8
Electric																																	Total Hours for Month	152 7/8
Process																																	Total Hours for Month	152 7/8
Anneal & Clean																																	Total Hours for Month	152 7/8
Dry																																	Total Hours for Month	152 7/8
Floor																																	Total Hours for Month	152 7/8
Help																																	Total Hours for Month	152 7/8
Mould.																																	Total Hours for Month	152 7/8
Floor																																	Total Hours for Month	152 7/8
Mould.																																	Total Hours for Month	152 7/8
Temp.																																	Total Hours for Month	152 7/8
Dept.																																	Total Hours for Month	152 7/8
2 Sec.																																	Total Hours for Month	152 7/8
Capola																																	Total Hours for Month	152 7/8
St. Fly																																	Total Hours for Month	152 7/8
St. Mould.																																	Total Hours for Month	152 7/8
Mach. & Draw																																	Total Hours for Month	152 7/8
Face																																	Total Hours for Month	152 7/8
Stone																																	Total Hours for Month	152 7/8
DAILY TOTAL HOURS																																	Total Hours for Month	1518 1/4

BOARD OF GOVERNORS { MONTHLY GRADE _____

REMARKS _____

FOREMAN _____

FIG. 4—STUDENT SHOP RECORD USED AS MASTER CARD

be shown the boy who is slow by discharging him, as he will feel it is the opinion of the executive force that he will not be successful in learning a trade, whereas by the extending of this probationary period the slow boy has often been found entirely satisfactory. We exercise great care to be certain that the boy is not adaptable before we discharge him. However, if the Board of Governors and the student's superiors conclude that he is not the material we require and it is useless for him to continue further, we are obliged to act accordingly.

Schedule of Work

Table 1 is the schedule of training for the Foundry Course.

Table 1

LIST OF DEPARTMENTS AND OPERATIONS IN WORK SCHEDULE AND LENGTH OF TIME SPENT AT EACH DIVISION

3-year Period	
Type of Work	Weeks
Clerical Work	3
Small Cores	12
Large Cores	12
Machine Molding	3
Bench Molding	12
Electric Furnace	6
Annealing and Cleaning	4
Dry Floor	8
Helping Molder	6
Floor Molding	44
Manganese Dept.	3
Cupola	2
Floor Molding—Gray Iron	27
Lecture, Mechanical Drawing and Math.	10
Vacation	3

THE PAY SCHEDULE FOR THE APPRENTICES

	Rate Per Hr.
1st period of 6 months.....	\$.40
2nd " " " "	.45
3rd " " " "	.50
4th " " " "	.55
5th " " " "	.62½
6th " " " "	.70

Supervision and Instruction

1. Supervision of Apprentices.

All our apprentices come under the supervision of the foremen. Although certainly desirable, we have not as yet felt warranted in employing an apprenticeship supervisor. We have endeavored, with reasonable success, to interest every foreman in our apprenticeship program whether he trains apprentices in his department or not.

2. Work Records and Reports.

A student shop record (Fig. 3) system has been adopted by us which we believe is compact, complete, easily understood, simple and practical. The student shop record is a daily report made out by the department clerk, who enters on this form the hours spent each day and the class of work for that day from information obtained from the time cards. In this way an ac-

Starting date 5-16-47

STUDENT SHOP RECORD

NAME John Doe CLOCK NO. 1647 MONTH Yearly Master YEAR

NAME OF MACHINE OR WORK	49 1/2 Hours - 1 Week							DAYS OF MONTH														MONTHLY TOTAL OF HOURS								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	23	24	25	26	27	28	29	30	31
2528 Hours - 1 Yr.								Total							Total							Total								
2549 " - 2 "								to							No.								to							
10094 " - 4 "								Date							Date							Date								
Clerical Work	3 Weeks-148.5 Hrs.																						Date							
Small Cores	12	"	59 1/2	"				49 1/2 49 1/2																						
Large Cores	12	"	59 1/2	"				99 99																						
Mach. Mould	3	"	148.5	"				168 1/2 168 1/2																						
Search Mould	12	"	59 1/2	"				94 1/2 94 1/2																						
Electric Furnace	6	"	297	"																										
Anneal & Clean	4	"	198	"																										
Dry Floor	8	"	59 1/2	"																										
Help Moulder	6	"	297	"				49 1/2 49 1/2																						
Prior Mould	44	"	2178	"				58 1/2 58 1/2																						
Mach. Mould	3	"	148.5	"																										
2 Vess. Cupola	2	"	99	"																										
Floor Mould	27	"	1356.5	"																										
Mach. & Draw.	10	"	495	"				24 24																						
Vacuum	3	"	148.5	"																										
DAILY TOTAL HOURS								151 1/2 151 1/2																						

BOARD OF GOVERNORS {

MONTHLY GRADE _____
 REMARKS _____
 FOREMAN _____

FIG. 5—FINAL STUDENT SHOP RECORD

curate account is kept of all operations. At the end of the month the total number of hours is posted on another card (Fig. 4) and then the daily record is forwarded to the Personnel Department where it is kept on file. At the end of the year it is posted on another card (Fig. 5) so that this system gives us a monthly, yearly and term record.

3. Arrangement of Transfers and Changes of Apprentices According to the Work Schedule.

The clerk of each department is held responsible for the transferring of the student from one operation to another. If the schedule specifies 500 hours and the apprentice works 475 hours he can be transferred to another department, if necessary, or the schedule can be extended to 525 hours if desirable on account of business conditions. However, we adhere strictly to the schedule whenever possible. Common sense and business conditions govern the schedule as our foundry is not of sufficient size to enable us always to move the apprentice exactly on the hour.

4. *Discipline.*

Although the Board of Governors has complete supervision over apprentices, we impress upon the boy that we insist upon strict discipline, and that while he is working in the various departments he must be governed by the rules of that department and must follow the foreman's instructions.

5. *Actual Instructions and Selection of Jobs to Be Done by Apprentices.*

All shop instructions are given by the foreman, who thoroughly outlines the job to the apprentice, should it be the first time the boy is assigned that particular job. When a student has advanced to floor molding he is assigned to one of our experienced floor molders, usually one who is interested in boys and preferably one having boys of his own, who instructs the apprentice and has sufficient interest in him to explain the reasons for the various operations. By this method of instruction the responsibility of training is placed on the experienced molder as well as on the foreman, thereby relieving the foreman of the details but not of the general supervision of the student. This method has been found highly successful.

When the molder and foreman agree that the student has progressed sufficiently to mold a casting without help, he is assigned work to do for which he is responsible, although it is the foreman's duty to see that the student is properly supervised and the work done satisfactorily.

Adjustment of Apprentice Work to Shop Operations

1. *Flexibility of the System to Take Care of Busy or Slack Periods.*

Although we attempt to follow the schedule of training as outlined as closely as possible, business conditions arise whereby additional help is needed at once in some department and we arrange to transfer the apprentices accordingly. We have in many instances done this, thereby greatly relieving the situation and helping the department that is falling behind. However, when the pressure in that department has been relieved we immediately transfer the apprentices back to the departments in which they were working before.

In slack periods we endeavor to keep our apprentices employed and do not lay them off as we would other employes. They are also allowed a week's vacation with pay each year.

2. *Advantage of Apprentices to Departments Where There Is Shortage of Help.*

We have many times relieved trying conditions in various departments in the foundry with excellent results. It has been gratifying to us and worth the effort necessarily put forth in the training of apprentices by building up an organization of this kind.

3. *Special Work for Apprentices with Outstanding Ability*

Arrangements for providing special work and training for those apprentices who show more than ordinary ability have not been made by our company but are contemplated in the future. In that program we will include for our foundry students a laboratory course, embodying metallurgy and the testing of materials, both chemical and physical.

School Attendance, Studies and Subjects Covered

1. *Proportion of Time in School and Location of Classes.*

Three hours per week are spent in the plant class room, one hour per week for mathematics, one hour for mechanical drawing and one hour for talks. The class instructor assigned to the class room is an employe of our engineering department. Talks to foundry students are conducted by one of our foremen who is well-versed in foundry practices and who has, in addition, some knowledge of chemistry. Regardless of how busy our foundry may be it does not prevent the apprentice from attending class work. The amount of mathematics and mechanical drawing given the student cover the subjects very thoroughly and enable him to carry on his work in the shop and gives him a foundation which will be of value to him if he is capable of becoming an executive. Talks to apprentices on practical shop problems cover gating, chills, sand, cupola and electric furnace practices. Both an outlined course and a round table discussion are held in the class room. Apprentices make notes during the week of any or various phases of their work which are not clear

PETTIBONE MULLIKEN SHOP SCHOOL

STUDENT'S ENROLLMENT CARD		Date of Enrollment
Name	<i>Jesse Lee</i>	Present address <i>4710 W. Harrison St.</i>
Date of Birth	<i>Jan. 8, 1908</i>	Birthplace <i>Chicago, Ill.</i> Nationality or Descent <i>American</i>
Grammar school attended	<i>Lapeer</i>	Grade or year completed <i>Graduated</i>
High school attended	<i>Lane</i>	Grade or year completed <i>"</i>
Evening school or college attended		Grade or year completed <i>"</i>
Father's occupation	<i>Meat Dealer</i>	Future ambition <i>City Superintendent</i>
Date entered P. M. Co. employ	<i>5/16/27</i>	Department employed in <i>Foundry</i>
Date entered as student	<i>"</i>	Department employed in <i>"</i>
Transferred from Dept.	to Dept.	Date of transfer
Reason for transfer		
Transferred from Dept.	to Dept.	Date of transfer
Reason for transfer		
Date completed student course		Date left P. M. Co.
Reason for leaving		Length of service
Date left school		Reason for leaving
Remarks		

FIG. 6a—FRONT FACE OF SHOP SCHOOL RECORD CARD

SHOP SCHOOL RECORD												
STUDY	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Math												
Mech Draw												
Hrs. Abs.												
Dept.												
Math												
Mech Draw												
Hrs. Abs.												
Dept.												
Math												
Mech Draw												
Hrs. Abs.												
Dept.												
Math												
Mech Draw												
Hrs. Abs.												
Dept.												

FIG. 6b—BACK FACE OF SHOP SCHOOL RECORD CARD

Name	<i>John Doe</i>	Dept.	<i>Idy</i>	Seat No.	<i>10</i>
Address	<i>4710 W. Harrison St.</i>		Date Employed	<i>5-16-27</i>	
Date of Birth	<i>Jan. 8, 1908</i>		Date Enrolled	<i>9-10-27</i>	
Clock No.	<i>1642</i>	Age	<i>19-9</i>	Education	<i>4-yr. H.S.</i>
<i>absentee letter sent 11-17-27. Reply sick</i>					

FIG. 7a—FRONT OF ATTENDANCE RECORD CARD

246 PM 12-24 500

ATTENDANCE RECORD							REGISTRATION No. <i>47</i>					
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
19 <i>27</i>						<i>1</i>	<i>1</i>				<i>3</i>	
19 <i>28</i>												
19 <i>29</i>												
19 <i>30</i>												
19												

FIG. 7b—BACK OF ATTENDANCE RECORD CARD

**SIGNATURES OF
PARENT OR GUARDIAN**

Period Ending 11-29-27

Period Ending _____

Period Ending _____

Period Ending _____

Period Ending _____

Period Ending _____

IMPORTANT

The success of the student depends largely on
your co-operation. Carefully note all marks.

**REPORT OF
STUDENT**

John Doe

**ON SHOP AND
SCHOOL WORK**



APPRENTICE COURSE
PETTIBONE MULLIKEN CO.
4710 W. Division St., Chicago, Ill.

FIG. 8a—FRONT AND BACK OF FOLDING REPORT CARD

to them and bring their problems into class where they are discussed.

2. *Plant Tours.*

To further the education and experience for our students, tours of other foundries are arranged for them. After each tour the students are required to submit a report on what they saw. Two tours per year are made which are interesting and instructive to the students and are, of course, a break in the routine work.

3. *School Records.*

Our shop school record (Fig. 6) is a form which is complete in itself and gives the school history of the student. This form gives us the desired information and includes an accurate record of the progress of the boy in class. We also have forms for attendance record of the student (Fig. 7).

We have a form for the student's monthly report (Fig. 8), which is filled out and sent to the parent or guardian to sign and return. This was adapted from the standardized form of the Chicago Board of Education. The parents appreciate receiving this report, as it shows the boys' progress month by month in their trade. The parents' co-operation has been very beneficial to us and has aided us in making our student training successful. The monthly report is the connecting link between the employer and the parent. In addition, we send the parent a Christmas greeting card. Usually we receive in return a New Year's card from the parent, which is evidence that he appreciates the connection between our company and himself.

Diploma

We have selected what we believe to be a very attractive diploma, (Fig. 9), which is signed by the officials of the com-

725 PM 1-28 1M

MONTHLY REPORT FOR THE
2nd HALF OF THE YEAR 1972

SUBJECT	PERIODS ENDING				
	12-1-77				
Accuracy	B				
Speed	B				
Thoroughness	B				
Initiative	A				
Conduct	A				
Mech. Draw.	C				
Math.	B				
Total Hours					
Hrs. Yet to Serve					
Absences					

EXPLANATION

- A—EXCELLENT. Better than most.
B—GOOD. Satisfactory and commendable.
C—AVERAGE. Neither very good or bad.
D—POOR. Of doubtful or failure grade.
E—FAILURE. Unsatisfactory, must be improved or will lead to discharge.

**SPECIAL REMARKS FOR
PERIODS ENDING**

11-79-77 He is capable to do better work in mechanical drawing if he applies himself.

FIG. 8b—CENTER PAGES OF FOLDING REPORT CARD



This Certificate declares that

*has satisfactorily completed the prescribed Apprenticeship Course
of years and has received the requisite practical training
to fit him as a journeyman*

*In Testimony thereof this Certificate is duly signed and
sealed at Chicago this day of 19.....*

Works Manager

Foreman

Secretary

FIG. 9—DIPLOMA ISSUED TO GRADUATE APPRENTICES

pany. When our apprentice graduates he receives his diploma and a cash bonus of \$100.00. At every graduation all students, together with foremen of the departments of the shop that have apprentices, assemble in our class room during working hours. The Works Manager presents the diploma and bonus to the graduate. This is followed by short talks by other officials of the company. The student is then considered a journeyman and is encouraged to stay in our organization.

We have found the apprentice training system outlined above to be successful because we have made it as practical as possible. We have been fair in all cases with our students and they, in turn, have been fair with us and have given us a good day's work for their pay and training.

By this system we are not only strengthening our own organization with good workmen and with prospective executives, but are also making worth while citizens, and last, but by no means least, we feel that we are contributing to the industrial world worth while, intelligent, American mechanics.

A Study of a Thirty-Six Inch Cupola*

BY F. B. COYLE,† NEW YORK, N. Y.

Prior to June, 1923, the Navy Department manufactured at the New York Navy Yard, Brooklyn, N. Y., a very good grade of cast iron for construction of Diesel engine parts for submarine service. About mid-year of 1923 it was decided to initiate a program of investigation with the object of still further improving the quality of the cast iron produced. This was necessary because of the severe demands created by expansion in submarine activities.

The properties of the material desired will only be discussed briefly here since that subject has been covered at length previously.¹ Past experience indicated that the best composition would be:

- (1) Low in carbon (about 3.20 per cent).
- (2) Low in silicon (about 1.20 per cent).
- (3) Low in phosphorous (under 0.20 per cent).

Such a composition was considered to best satisfy the following requirements:

- (1) Maximum strength.
- (2) Maximum resistance to wear (Brinell hardness 180 to 210).
- (3) Minimum tendency for porosity to develop.
- (4) Minimum growth due to repeated heating.

*Published by permission of the Director of Naval Intelligence.

†Research Metallurgist, International Nickel Co., Bayonne, N. J.

¹*Properties and Heat Treatment of Cast Iron for Diesel Engines.* F. B. Coyle. Transactions, American Society for Steel Treating, Sept., 1927.

Discussion of this paper begins on page 671.

Of course, at that period the development of alloy iron had hardly been conceived and this paper necessarily refers only to plain cast iron.

The cupola process for melting iron is crude in comparison with usual methods used for melting other metals. This is probably due to the fact that this melting method has not received sufficient attention and its full possibilities remain undeveloped. Therefore, it was decided to analyze as closely as possible the cupola process in order to ascertain what, if any, were the characteristics of the process. The object in mind was that possible refinements of the melting process might increase the uniformity and quality of the iron produced.

At that time the production of Diesel engine castings was such that the smallest of three available cupolas (one lined to 36 inches diameter) would melt all of the metal required. Occasionally a 42 inch cupola was used. The dimensions of the 36 inch cupola were checked and showed that the construction was well balanced. The tuyeres were located 18 inches above the bottom doors. Thus the capacity of the well, or crucible of the cupola, was about 3,000 pounds of molten metal. Metal was tapped intermittently since this size cupola is not adaptable to continuous delivery. There were four tuyeres, each 4 inches by 14 inches. The ratio of tuyere area to cupola area was 1 to 4.5. One tuyere was one inch lower than the others in order to permit overflow into the windbox. The slag hole was located two inches below the lowest tuyere. The blast pipe was 12 inches in diameter. The ratio of blast pipe area to tuyere area was 1.62 to 1. The windbox was $7\frac{1}{2}$ inches wide and $44\frac{7}{8}$ inches high, the cross sectional area being three times the area of the blast pipe. The height of the charging door above the bottom doors was 11 feet or 3.7 times the diameter of the cupola.

Fourteen heats were run and as many details of each, as practicable, were studied. As many characteristics as possible were maintained constant on each heat, but one or two characteristics were intentionally altered on subsequent heats. The object was, then, to determine by statistical analysis the effect of variation of each characteristic. The following data was recorded on each heat:

- (1) Height of coke bed in inches.
- (2) Blast pressure in inches of water at start and when each ladle was tapped.
- (3) Time from start when first metal run out of the tap hole.
- (4) Total pounds metal melted during each heat.
- (5) Total time of run.
- (6) Pounds per hour melted.
- (7) Coke charges (weight).
- (8) Iron charges (weight).
- (9) Time of slagging.
- (10) Mixture charged.
- (11) Time of tapping each ladle.
- (12) Estimated weight of each ladle.
- (13) Temperature of the metal running over the spout of each ladle and the temperature of the metal entering the mold of the most important casting.
- (14) Record of all castings poured from each ladle.
- (15) Test pieces from as many ladles as possible for chemical analysis, tensile strength, and Brinell hardness.

The fact that many of the data shown in this paper are considered general knowledge is appreciated. However, the author after extended search of the literature was not able to discover a concise, systematic treatise presenting such information. Much of the information, it will also be agreed, is new. It is the aim of the author to present these data in a concise, systematic form, with the hope of stimulating further investigation and presentation of data, particularly on various sizes and types of cupolas with the ultimate view of increased cupola melting efficiency.

Data of Individual Heats

The data collected during each heat are given in Figs. 1 to 14, inclusive, and the average results for each heat are given in Fig. 15. Following is a resumé of the salient features of each of the individual heats.

Heat No. 30 (Fig. 1). During this heat the blast pressure was maintained uniform throughout by adjusting the slide valve in the blast pipe. It is evident that the stack became clogged between 1:50 and 2:12 and the volume of air entering the stack was diminished.² Consequently, the melting rate was temporarily reduced during that period. After the obstruction disappeared, the volume of air and the melting rate were increased. The temperature of the first metal tapped out (at 1:39) was low and during the period immediately following the carbon, silicon and sulphur increased slightly. Toward the end of the heat, carbon, silicon and sulphur were reduced again. The blast was shut off for 1½ minutes at 1:30 because the tap hole was fused solid and metal ran out into the windbox. It was not possible to cast a test piece from this tap.

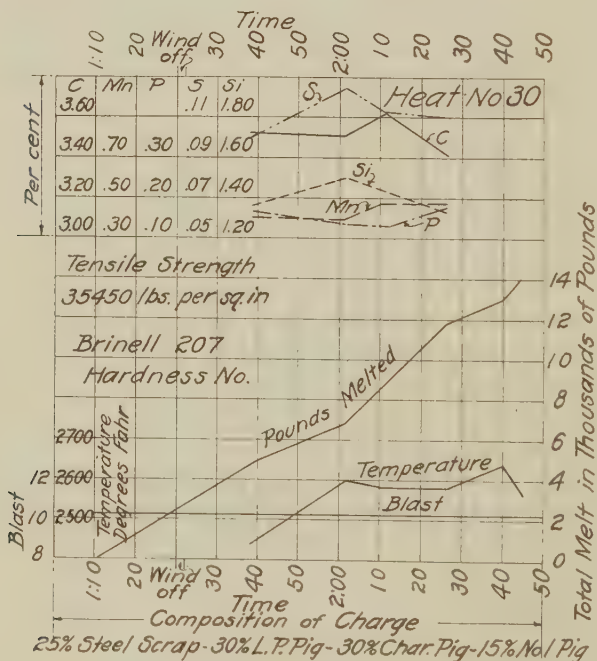


FIG. 1—HEAT 30

²When time is referred to in hours and minutes, reference is made to the actual period as indicated in the various charts. When melting rate is referred to, the time lapse is taken from the time the first iron appears at the spout. Average melting rate was calculated from the time first iron appeared at the spout until the bottom was dropped.

Heat No. 31 (Fig. 2). The melting rate was rather low at the beginning of the heat, but was faster after 2:25. The blast pressure was reduced progressively after 2:25. The object was to permit a uniform volume of air to pass through the cupola, since as the stack shortened and consequently the resistance to the flow of air was reduced, less pressure was required to force the same volume of air through the stack. However, the pressure was reduced too soon, as shown by the falling off in temperature between 2:25 and 3:00 o'clock. After 3:00 o'clock the pressure was sufficient to supply the proper amount of air and the temperature was increased. It will be noticed that during the period when the temperature was low, carbon and silicon increased. This closely follows the effect shown in Fig. 1, that carbon and silicon increased after a period of low melting temperature. It is evident that it was not necessary to lower the blast pressure sooner than 25 or 30 minutes before the end of the heat or until only 2,000 pounds of the metal remained unmelted.

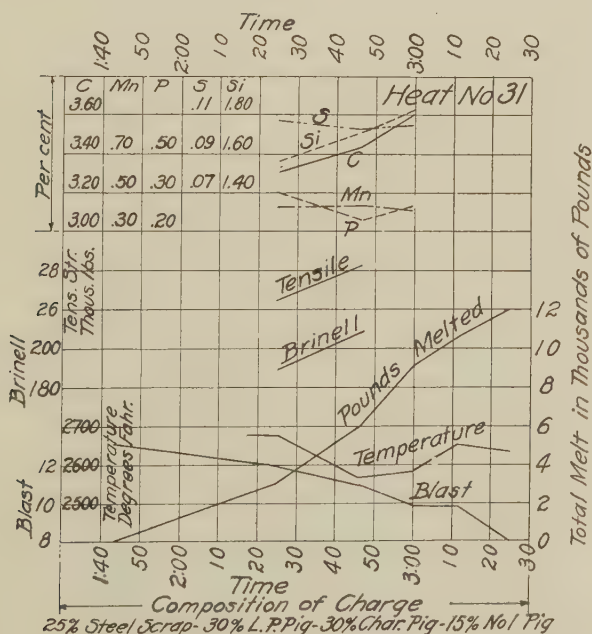


FIG.2—HEAT 31

Heat No. 32 (Fig. 3). The melting rate and most other characteristics were quite uniform throughout the heat. The blast pressure was lowered about two inches during the last 50 minutes of the heat. It will be noticed that the temperature, while low at first, increased uniformly until 12,000 pounds had been melted. Afterward the temperature remained quite constant. Carbon reduced steadily to the middle of the heat and then increased. Silicon was reduced steadily from about 1.70 per cent at the beginning to about 1.40 per cent at the end of the heat. The silicon on each of these three heats was higher than that calculated, no doubt due

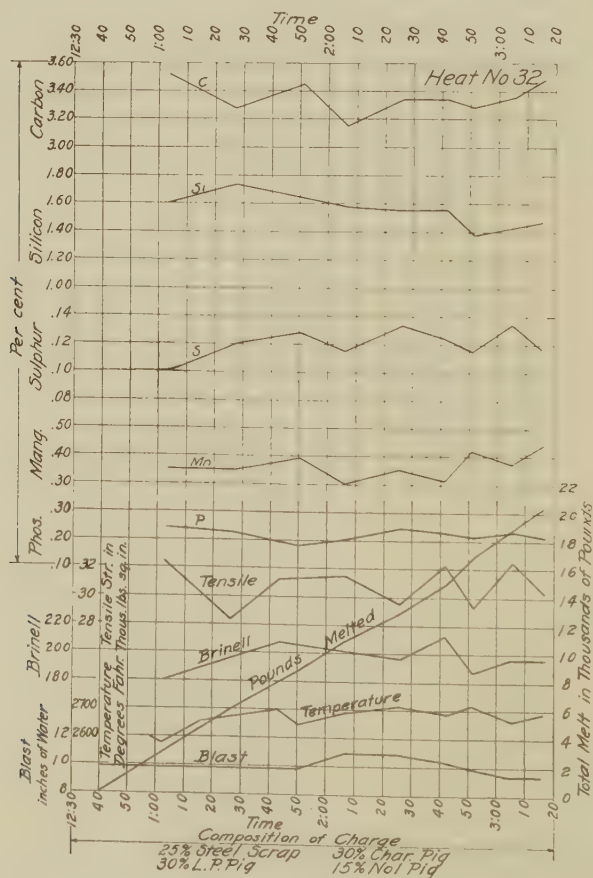


FIG. 3—HEAT 32

to the fact that the silicon in the No. 1 pig was actually higher than that shown by analysis.

Heat No. 33 (Fig. 4). During this heat two different mixtures were charged. The calculated compositions of both mixtures were the same except that the first mixture contained sufficient Mayari pig iron to produce about 0.25 per cent chromium and 0.25 per cent nickel in the molten metal. No extra coke was charged between the two mixtures. The time required to melt the first 2,000 pounds was calculated from Heats 30, 31 and 32. When it was considered that all of this metal was melted down it was tapped out. The second ladle contained only a trace of chromium and nickel which demonstrated that separation of the

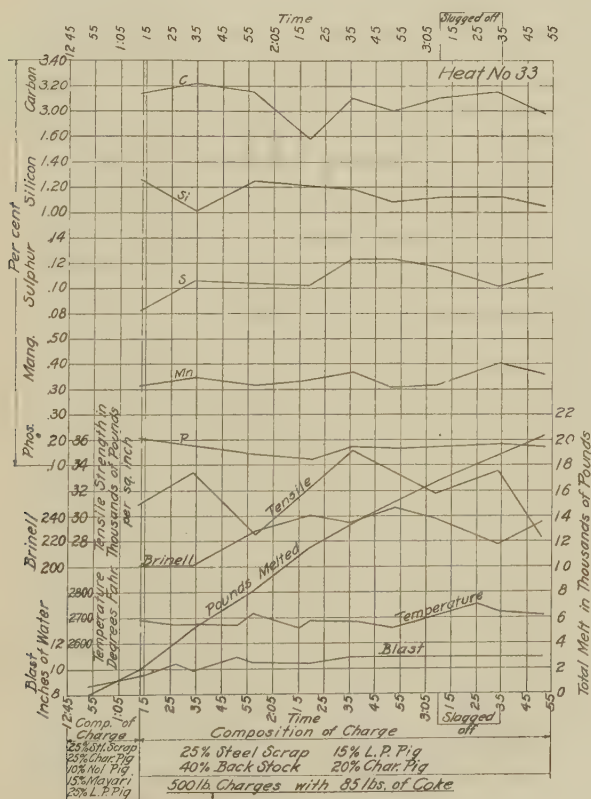


FIG. 4—HEAT 33

two mixtures had been effected. Most other characteristics were uniform during the heat. However, the melting rate slowed down after 2:20 (after the sixth ton). This may have been caused by an accumulation of slag. The carbon was exceptionally low on the fourth tap. This occurred after 11,500 pounds had been melted. The only possible explanation is that the metal was tapped before a complete charge had been melted and that this ladle actually contained a higher percentage of steel than anticipated. If this were true, it could be expected that the next ladle would be high in carbon. However, this was not the case. Both silicon and carbon decreased about 0.20 per cent from the beginning to the end of the heat. The temperature increased after slagging off. Since no limestone was charged, the slag consisted essentially of iron silicate.

Heat No. 34 (Fig. 5). The increase in temperature after 2:10, when one per cent limestone was added to all charges, is notable. Carbon and silicon showed a tendency to decrease as the

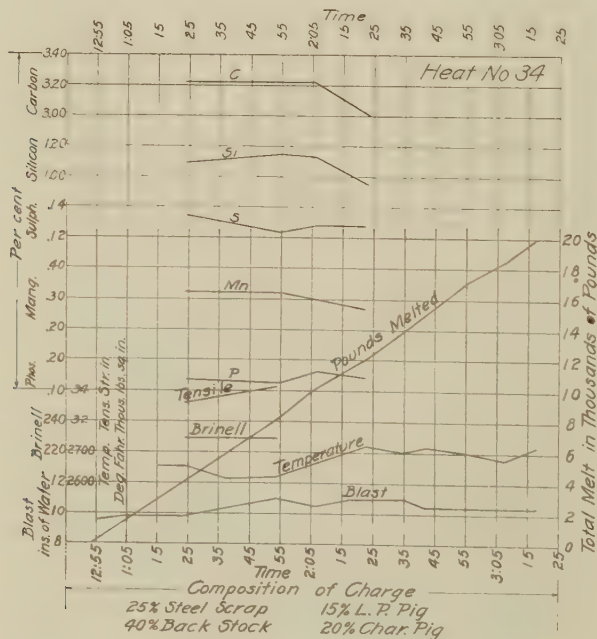


FIG. 5—HEAT 34

heat progressed but not enough test bars were cast to show this tendency to the end of the heat.

Heat No. 35 (Fig. 6). Two mixtures were charged and kept separate in the same manner and with the same results obtained during heat No. 33. The results of this heat were erratic. The blast pressure was low throughout and considerable slag accumulated. The tensile strength and Brinell hardness varied over a wide range. During the slagging periods manganese and silicon

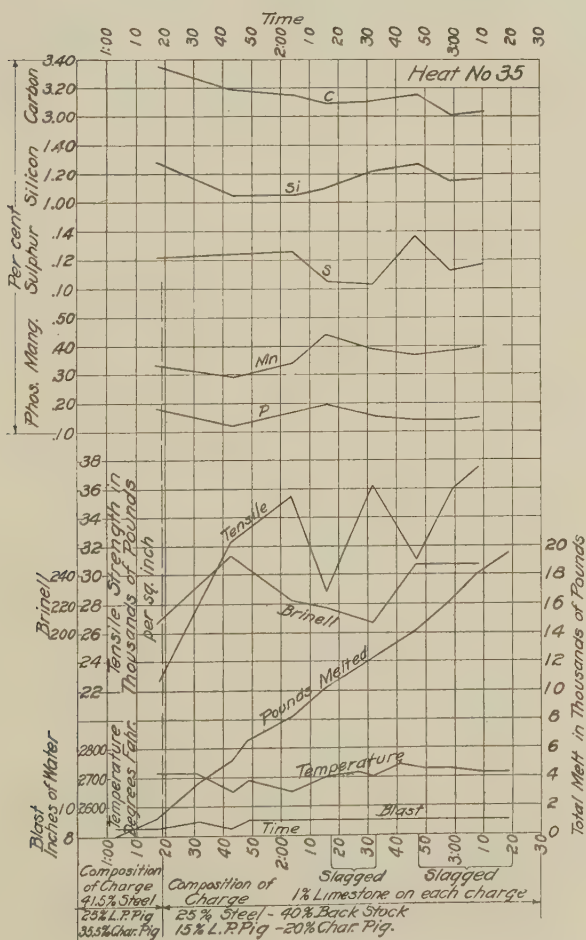


FIG. 6—HEAT 35

increased and sulphur showed a tendency to decrease. Carbon decreased 0.40 per cent at a uniform rate from beginning to the end of the heat. The temperature showed a drop during the second quarter. The melting rate, however, was uniform. The tensile strength was low at the two points where slag had accumulated.

Heat No. 36 (Fig. 7). Two mixtures were charged during this heat, but unlike Heats 33 and 35, the change from the first to the second mixture was made in the latter third of the heat. The weight of the metal tapped into each ladle was calculated in the following manner: Each ladle was weighed empty and again when full of molten metal. An iron rod was then dipped into the metal until the tip touched the bottom of the ladle. The portion of the rod which had been inserted in the metal was red hot and the depth of metal in the ladle was measured therefrom. The

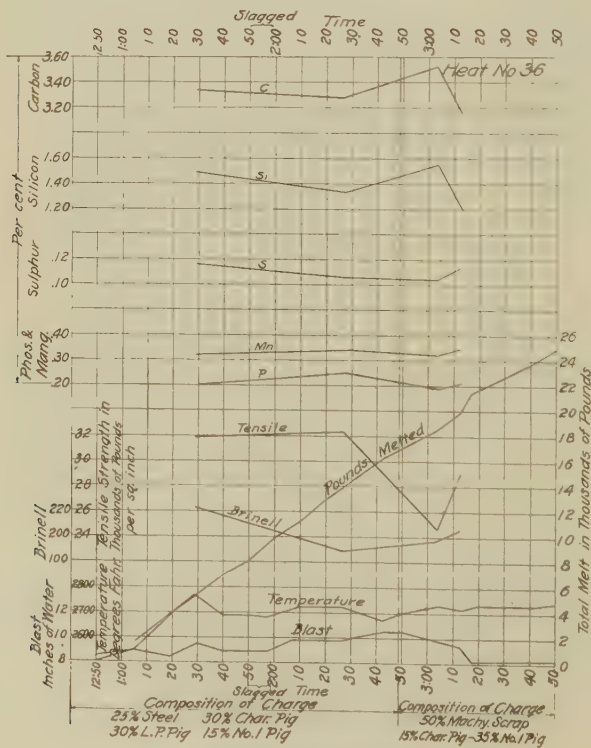


FIG. 7—HEAT 36

weight of metal per inch of immersion was then calculated. By inserting an iron rod in this manner it is possible to estimate the weight of metal in a ladle quite accurately. No extra coke was charged between the two mixtures, which were accurately separated, as shown by the physical and chemical properties. It is apparent from this and preceding heats, that the nature of the charge has considerable effect upon the physical properties. That is, the higher the percentage of scrap the greater the variation in physical properties. The blast pressure was low during the first part of the heat (prior to 2:00 o'clock) and considerable slag accumulated. After slagging off, the blast pressure was increased

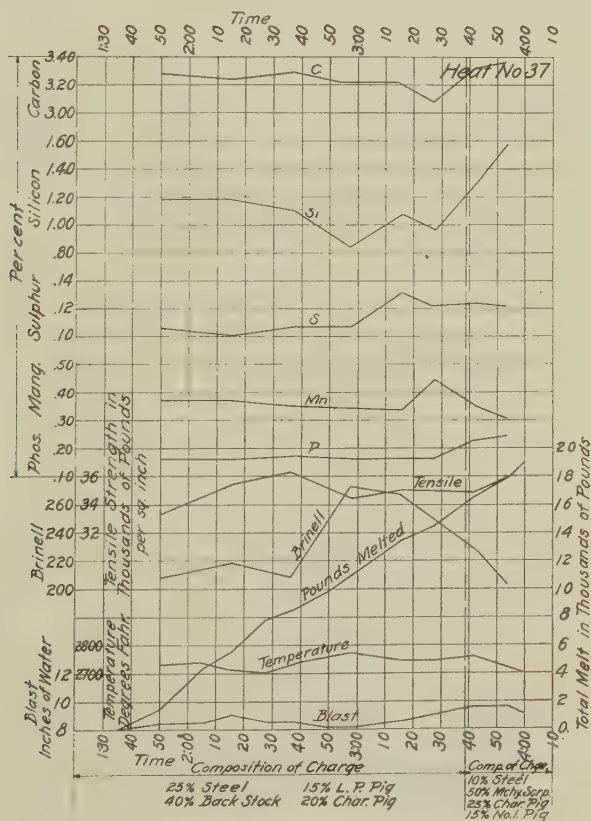


FIG. 8—HEAT 37

and not enough slag accumulated during the latter two-thirds of the heat to make it necessary to slag off. Carbon and silicon showed a tendency to decrease as melting of each mix progressed.

Heat No. 37 (Fig. 8). While the blast pressure was low and the temperature was high throughout the heat, both were uniform. The melting rate varied somewhat during the first part of the heat. Two mixtures were charged. It is possible, as shown by the chemical composition and Brinell hardness, that a small quantity of the first mixture was mixed with the second mixture. This is indicated by the trend of the silicon and phosphorous graphs. The silicon content decreased considerably and the carbon slightly during the melting of the last part of the first mixture. The Brinell hardness varied inversely as the silicon content. It is pos-

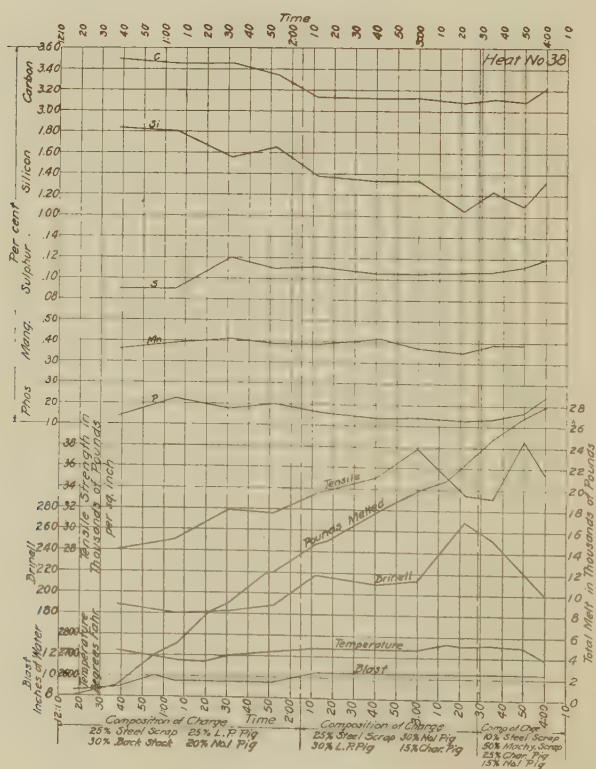


FIG. 9—HEAT 38

sible that complete melting of the various charges did not occur regularly. Possibly some pieces of steel or cast iron scrap were not completely melted while passing through the melting zone, but were melted later in the bath of metal in the crucible of the cupola.

Heat No. 38 (Fig. 9). Three mixtures were charged with this heat and all well separated. The composition was maintained uniform in each section except silicon and carbon, which decreased steadily as the melting of each charge progressed. The first mix-

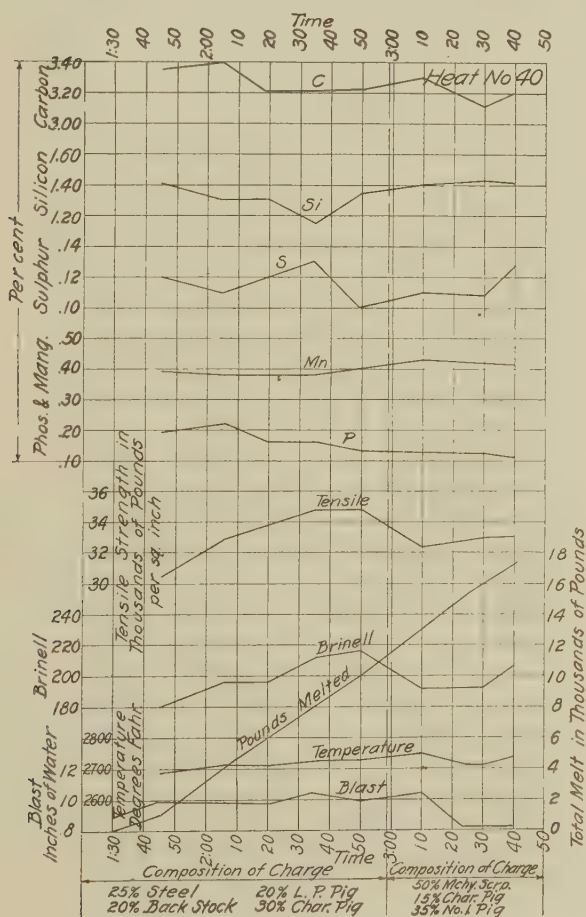


FIG. 10—HEAT 40

ture was calculated to give higher carbon and silicon than the others. The melting rate slowed down after the first mixture was all melted. This result can be expected because the lower silicon and carbon correspond to a higher melting point. Although 14 tons were melted during the heat, not enough slag accumulated to necessitate slagging off. All of the material charged was very clean and quite free from sand. No limestone was charged.

Heat No. 40 (Fig. 10). All of the characteristics were quite uniform. The tensile strength and the Brinell hardness of the first ladle as shown in practically all of the heats is lower than shown

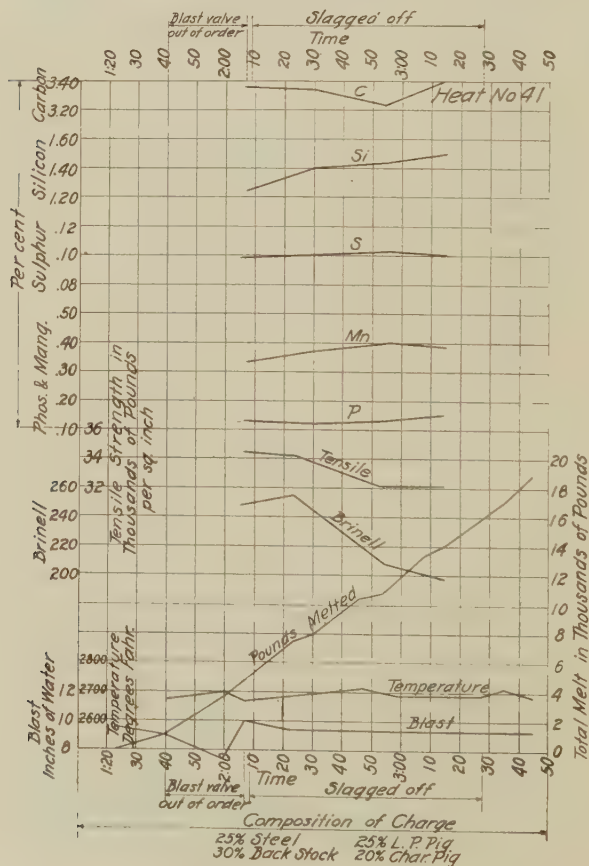


FIG. 11—HEAT 41

by tests from the remaining portions of the heats. Carbon and silicon of the first two mixtures decreased as the heat progressed.

Heat No. 41 (Fig. 11). The blast valve was defective during the first part of the heat and consequently the blast pressure varied considerably until it was fixed at 2:07 o'clock. Following the period when the blast pressure was low considerable slag accumu-

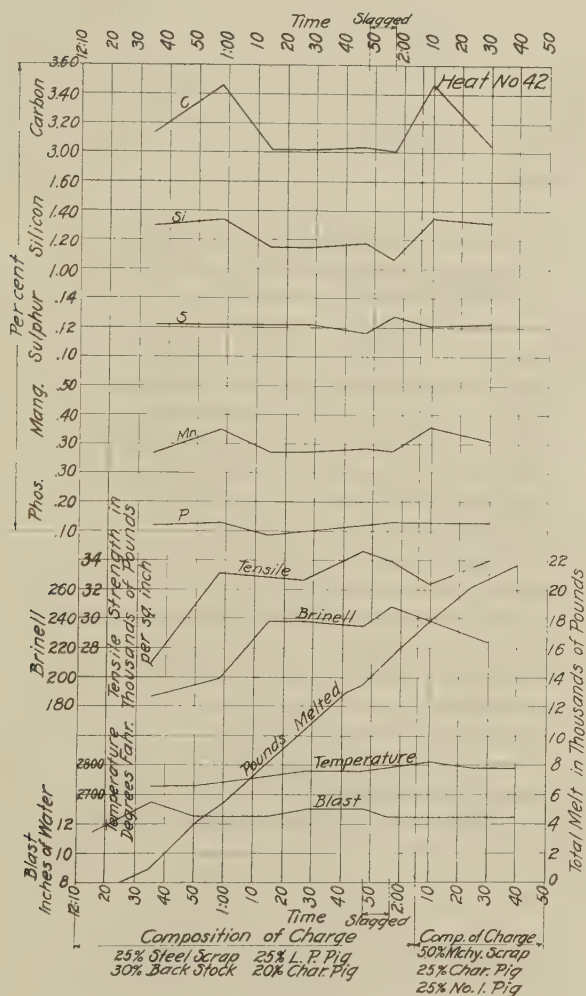


FIG. 12—HEAT 42

lated and the slag hole remained open from 2:09 until 3:28. During the period of slagging off, silicon and manganese increased. Carbon remained uniform. Since no limestone was charged the slag was essentially iron silicate. The tensile strength varied inversely as the silicon.

Heat No. 42 (Fig. 12). The heat was uniform throughout.

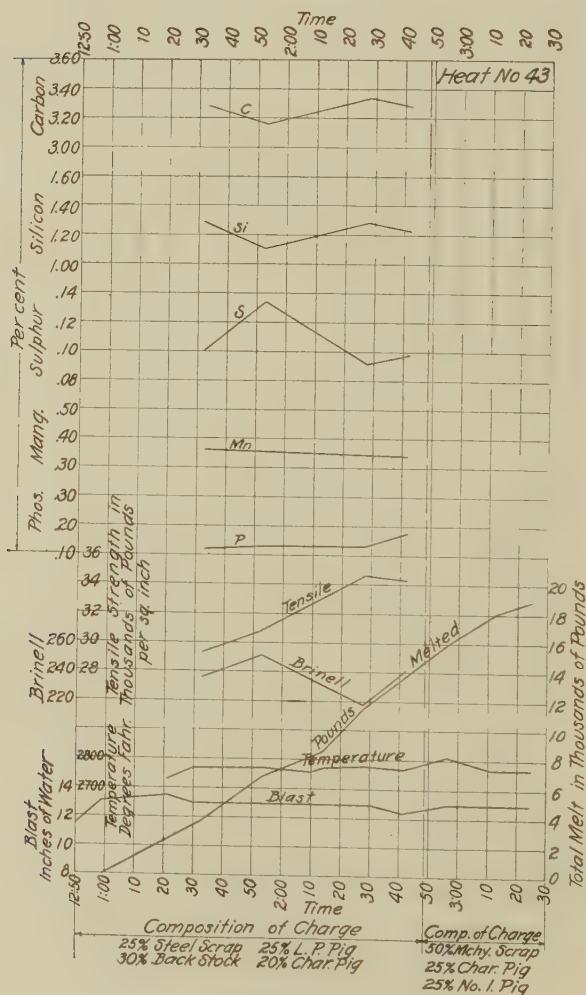


FIG. 13—HEAT 43

The strength of the first ladle was much lower than that of the following ladles. Carbon and silicon decreased and the temperature increased as the heat progressed.

Heat No. 43 (Fig. 13). The characteristics were uniform. The blast was higher than on the former heats and the temperature was also higher. Again the first ladle showed lower tensile strength than succeeding ladles. The uniformity of carbon and silicon during the heat was conspicuously different from the previous heats.

Heat No. 45 (Fig. 14). As during heat No. 43, the blast pressure and temperature were both high. While most characteristics continued uniform during the heat, carbon and silicon were consistent with all heats except No. 43, which showed a decrease as the heat progressed.

Review of Conditions

A review of the foregoing presents the following general impressions:

(1) Addition of limestone to metal charges increases the temperature of the metal tapped from the cupola.

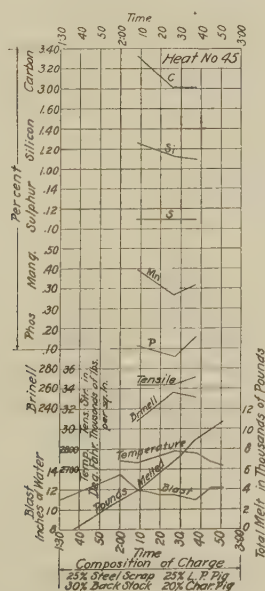


FIG. 14—HEAT 45

(2) Carbon and silicon decrease as a heat progresses although all metal and fuel charges remain the same.

(3) The temperature of the metal tapped from a cupola increases as a heat progresses.

(4) Sulphur is low during periods of slagging off and is high when slag accumulates.

(5) The strength and hardness of the metal cast from the first ladle are lower than obtained from metal from succeeding ladles of the same heat.

Conclusions Drawn from Average Conditions of Heats

The average conditions of each of the foregoing heats are shown in Fig. 15. From this chart, the following general relations are apparent:

(1) Contrary to the general opinion among foundrymen, the use of back stock (or return scrap) has no effect upon the sulphur content of the melted metal. The percentage of this element depends upon melting conditions. An examination of the record of Heat 35 (Fig. 6) indicates that the occurrence of slag also corresponds with slightly higher sulphur (about 0.02 or 0.03 per cent higher). In this heat the slag was practically pure iron silicate. In Heat 34, when one per cent of limestone was charged during the latter part of the heat, the acidity of the slag was reduced and consequently no effect is shown upon the sulphur. The slag shows indications of being basic enough to slightly affect phosphorus.

(2) As the weight of metal charges decreased, both the temperature and melting rate increased. It is indicated that there is a definite weight of metal charge which will produce the best melting conditions. In the cupola investigated, 1,000 pound charges are best because of the higher temperature and melting rate. The 500 pound charges used at the beginning of heat No. 33 showed no improvement over the use of 1,000 pound charges and would entail increased handling expense.

(3) Tensile strength in general varies directly as the temperature and melting rate. The temperatures of melting obtained in this investigation are higher generally than in usual industrial

practice. Two years ago Piowowsky³ showed that there is a critical temperature of superheating which will produce cast iron with improved strength. This temperature, which was determined from crucible melts, was found to be about 2730 degrees Fahr. and corroborates the results of this review in 1923, that with cupola melting temperatures high enough to give a temperature of 2730 to 2750 degrees Fahr. at the spout, the tensile strength will be increased about 30 per cent.

(4) Blast pressure is a very important factor in controlling melting rate. The higher the blast pressure (without being too

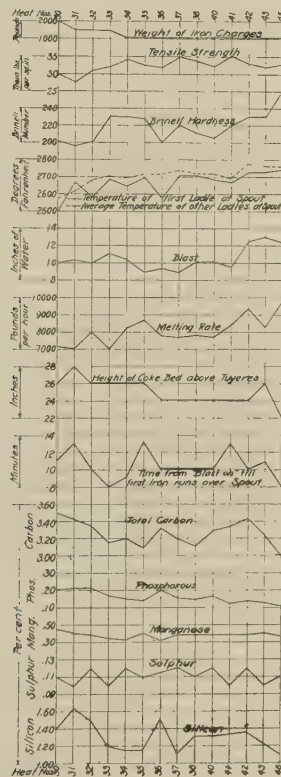


FIG. 15—AVERAGE OF CONDITIONS OF HEATS NOS. 30 TO 45

³Progress in the Production of High Duty Cast Iron. E. Piowowsky. Trans. A. F. A., 1926.

high to cause oxidation) the faster the melting rate. Of course, pressure as a means of regulating blast is a crude method of measurement. Subsequently it has been found that the use of a volume meter or some method of measuring air, as by weight, is the only reliable and dependable means of measuring blast. However, the vast majority of foundries still depend upon pressure as a guide. In fact, it is surprising how many foundrymen do not even use this method of measurement.

Composition of Charges

The composition of the materials used in making up the various charges is given in Table 1:

Table 1
COMPOSITION OF MATERIALS CHARGED

	Total	Per Cent				
		C.	Mn.	P.	S.	Si.
Steel scrap	.45		.85	.10	.070	.10
Low phosphorus pig	3.74		.13	.044	.020	2.33
Charcoal pig	3.70		1.10	.20	.025	1.60
No. 1 pig	3.70		.63	.74	.020	2.22
Back stock	3.30		.50	.20	.100	1.40

Composition of Mixtures Obtained from Calculated Charges

Table 2 gives the average composition, by analysis, of all of the heats in which the particular mixtures were charged. At the bottom of the table are given the averages of each type of charge. It must be borne in mind that the calculated compositions of all of the charges were identical. The silicon of the all-pig mixture is 0.30 to 0.40 per cent higher than calculated, probably because the No. 1 pig was actually higher in silicon than the analysis indicated. While the elimination of No. 1 pig in higher scrap mixtures would account for some of the reduction in silicon in Fig. 16, it would not account for all of it. This view is substantiated by the parallel trend of both the carbon and silicon graphs.

Table 2
COMPOSITION OBTAINED FROM VARIOUS CHARGING MIXTURES

—All Pig—			—20% Scrap—			—30% Scrap—			—40% Scrap—		
C.	Mn.	Si.	C.	Mn.	Si.	C.	Mn.	Si.	C.	Mn.	Si.
3.50	.45	1.40	3.30	.38	1.30	3.12	.38	1.30	3.16	.34	1.20
3.42	.40	1.64	....	....	....	3.35	.38	1.32	3.20	.32	1.16
3.35	.38	1.50	....	....	....	3.43	.38	1.36	3.10	.40	1.16
3.32	.32	1.50	....	....	....	3.25	.40	1.22	3.20	.38	1.10
AVERAGES											
3.40	.39	1.51	3.30	.38	1.30	3.28	.38	1.26	3.17	.38	1.15

The compositions given in Table 2 are plotted in Fig. 16. While a loss of 30 per cent manganese was allowed in all calculations, the actual loss was about 33 per cent. Carbon gained about 17 per cent and silicon was reduced about 5 per cent. However, the changes using all-pig mixtures were slightly less than these figures and the changes were slightly more for the high scrap mixtures. On the other hand, sulphur, phosphorus and manganese were practically uniform no matter what mixtures were used. Ordinarily these results would not be expected because a comparison of the heats of formation of the oxides of these elements would indicate a greater reduction in manganese. But little is

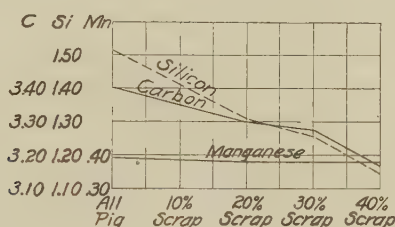


FIG. 16—EFFECT OF SCRAP IN CHARGE ON COMPOSITION OF MELTED METAL—CALCULATED COMPOSITION OF ALL CHARGES THE SAME

known of the simple equilibrium conditions of these elements or of their equilibrium in the presence of their oxides, carbon and carbonaceous gases at elevated temperatures. Therefore, the recorded results are presented without further comment.

In Table 3 is given the maximum and minimum values obtained for carbon, manganese and silicon in each heat. The average variations (difference between minimum and maximum) are given at the bottom of each column. These averages represent the normal variation of the various elements which can be expected during a heat and can be summarized as follows:

Element	Range of Variation	Over or Under Desired Amount
Carbon	0.30	0.15
Manganese	0.10	0.05
Silicon	0.25	0.125

The variation in phosphorus and sulphur is very small.

Table 3
VARIATION OF ELEMENTS DURING EACH HEAT

No.	ALL FIG			20%			30%			40%			SCRAP			SCRAP											
	Carbon Min. Max.	Mang. Min. Max.	Silicon Min. Max.	Heat	Min.	Max.	Carbon Min. Max.	Heat	Min.	Max.	Carbon Min. Max.	Heat	Min.	Max.	Mang. Min. Max.	Carbon Min. Max.	Heat	Min.	Max.	Silicon Min. Max.							
30	3.42	3.62	.41	.49	1.33	1.50	40	3.20	3.40	.38	.42	1.16	1.40	38	3.36	3.50	.36	.41	1.56	1.84	33	2.80	3.22	.31	.40	1.02	1.05
31	3.20	3.60	.42	.49	1.56	1.82	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
32	3.15	3.52	.30	.43	1.37	1.73	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
36	3.28	3.34	.32	.34	1.33	1.49	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
Av.	.24	.10	.24	.20	.04	.24	.24	.07	.205	.29	.10	.25				.29	.10	.25									

Data Analyzed

The data collected during the various heats were further correlated to show what relation existed between other operating characteristics.

24 Inch Bed Gave Highest Temperatures and Best Strengths

In Fig. 17 has been plotted the relation between melting temperature and height of bed for various blast pressures. The

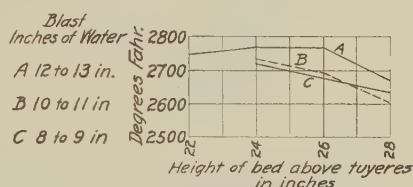


FIG. 17—RELATION BETWEEN HEIGHT OF COKE BED AND TEMPERATURE AT VARIOUS BLAST PRESSURES

pressure was recorded in inches of height of a water manometer. It is apparent that a bed of coke 24 inches above the tuyeres produced the highest temperature in the molten metal. While this low bed will not be considered orthodox, it gave the best results in this case, and after all results are what count.

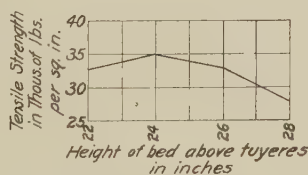


FIG. 18—EFFECT OF HEIGHT OF BED CHARGES VERSUS STRENGTH OF METAL

The average tensile strength of the various heats has been plotted against the height of bed in Fig. 18. It is clear from Figs. 17 and 18 that a bed of coke 24 inches above the tuyeres produces a better quality of metal than a bed of any other height.

Size of Metal Charges Affects Melting Rate

Fig. 19 shows that the weight of metal charges has a decided effect upon the melting rate. With small charges the metal and coke are more intimately mixed and the melting efficiency greater

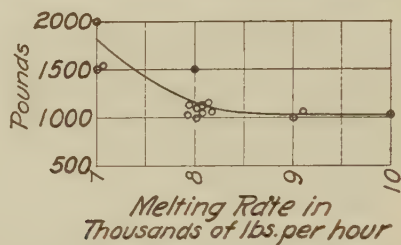


FIG. 19—MELTING RATE VERSUS WEIGHT OF CHARGES

than with large charges. It is apparent that 1,000 pound charges are most advantageous for this size cupola. An inspection of heat No. 33 shows that nothing is gained by the use of smaller charges.

Increase in Blast Pressure Increases Iron Temperatures

In Fig 20 is shown the variation of the temperature of the molten metal with the blast pressure in both the 36 inch cupola

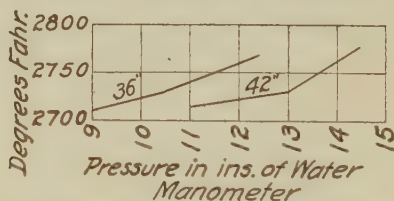


FIG. 20—BLAST PRESSURE EFFECT UPON TEMPERATURES

and a 42 inch cupola. Since the dimensions of both cupolas were well balanced, it is apparent that a higher blast pressure is required in a large cupola than in a small one in order to force the air to the center of the cupola. It is clearly shown that to obtain the highest possible temperature of molten metal the blast pressure of a 36 inch cupola should be $12\frac{1}{2}$ inches of water, and for a 42 inch cupola $14\frac{1}{2}$ inches of water.

The relation between the blast pressure and temperature for

various melting rates is shown in Fig 21. The normal melting rate of a 36 inch cupola is 8,000 pounds per hour. Fig. 21 clearly shows that the higher the blast pressure the higher the temperature of the molten iron. When the melting rate is be-

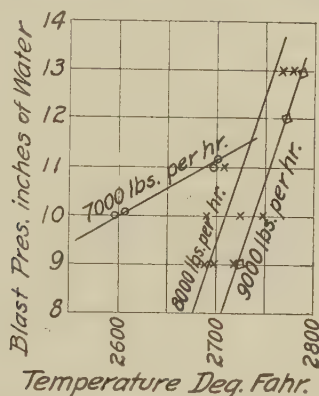


FIG. 21—RELATION BETWEEN BLAST PRESSURES AND TEMPERATURES FOR VARIOUS MELTING RATES

tween 8,000 and 9,000 pounds per hour, the variation in temperature for all melting rates is proportional to the blast pressure. However, when the melting rate is below normal a small change in pressure at the lower pressures has a greater effect than at the higher pressures.

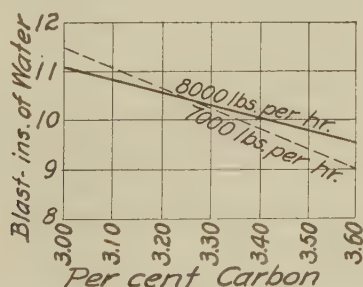


FIG. 22—RELATION OF BLAST PRESSURES AND PER CENT CARBON TO MELTING RATE

Increase in Blast Pressure Lowers Total Carbon

In Fig. 22 the blast pressure has been plotted against the total content of carbon for two melting rates. This figure dem-

onstrates that a lower carbon content accompanies high blast pressure. It is possible that the percentage of carbon is probably a function of time. The sequence being: High blast pressure effects fast melting; the molten metal passes through the sub-melting zone section faster and does not lose as much heat to the cooler gases.

Relation of Melting Rate and Temperature

The variation of melting rate with temperature is shown in Fig. 23. The lower graph gives the relation for the first ladle tapped and upper graph the average temperature of the remaining ladles tapped during the various heats. That a certain amount of

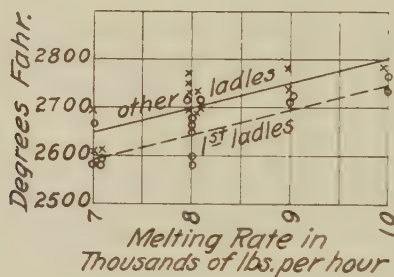


FIG. 23—VARIATION OF MELTING RATE WITH TEMPERATURES

heat is extracted from the first metal melted to bring the temperature of the bottom and sides of the crucible of the cupola as well as the coke of the bed to the same temperature as that of the molten metal probably explains why the first metal tapped is cooler than that which follows.

Total Carbon Decreased With Faster Melting

The variation of total carbon with melting rate at various temperatures is shown in Fig. 24. The higher the temperature the lower the total carbon. In each temperature range, the faster the melting rate the lower the total carbon. This again is not quite orthodox because it is natural to assume that the higher the temperature the higher the carbon due to increased ability of the

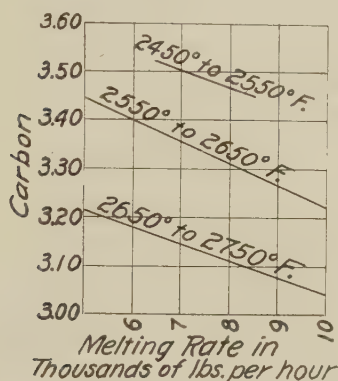


FIG. 24—VARIATION OF TOTAL CARBON WITH MELTING RATES AT VARIOUS TEMPERATURES

iron to dissolve carbon. Nevertheless, Fig. 24 presents the facts as they were obtained.

Higher Temperatures Gave Increased Strength

In Fig. 25 the relation between tensile strength and temperature of melting is shown. This figure demonstrates that the higher the melting temperature the stronger the iron within the range studied. While Piwowarsky has shown by his experiments with crucible melts that the quality of cast iron begins to diminish

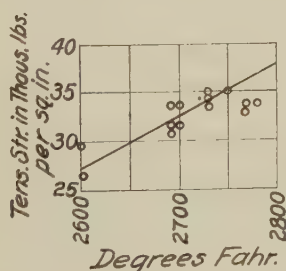


FIG. 25—RELATION BETWEEN TENSILE STRENGTH AND TEMPERATURE

with melting temperatures in excess of 2,800 degrees Fahr., it is hardly possible to obtain such high temperatures in ordinary cupola practice. Higher temperatures could doubtless be obtained by using a pre-heated blast or by other special means.

Lower Total Carbon Increased Strength

The relation between the average tensile strength and total carbon is shown in Fig. 26. The lower the total carbon the higher the tensile strength.

Effects of Slagging

The effect of slagging has been indicated in the description of Heat 35 (Fig. 6). It is possible, as shown by Fig. 6 (heat No. 35) that a layer of slag acts as a cover and prevents loss of silicon and manganese. However, it will be noticed that during all heats in which much slag accumulated there was considerable variation in tensile strength and Brinell hardness. When the blast pressure was over 10 inches of water, practically no slag formed. For short heats it has been found advisable to charge as clean material as possible and keep the slag formed at a minimum and this practice has been adopted.

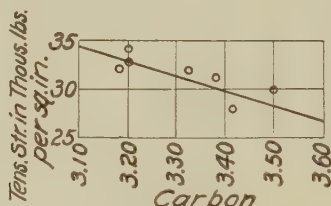


FIG. 26—VARIATION OF TENSILE STRENGTH AND TOTAL CARBON

Data Collected Used for Melting Control

The data collected in this analysis were used as a basis for standardizing the subsequent operation of the 36 inch cupola studied. Conditions were regulated as follows:

Coke bed.....24 inches above the tuyeres

Metal charges....1,000 pounds

Blast pressure...12 inches of water

Coke ratio.....1 to 6.5 of metal

Flux None

All metal charges consisted of

25 per cent scrap steel

20 per cent back stock (return scrap)

45 per cent pig iron (low phosphorus pig and charcoal pig),

and were calculated to give the following composition:

<i>Element</i>	<i>Per cent</i>
Carbon	3.20
Manganese	.40
Phosphorus	.20
Sulphur	.12
Silicon	1.20

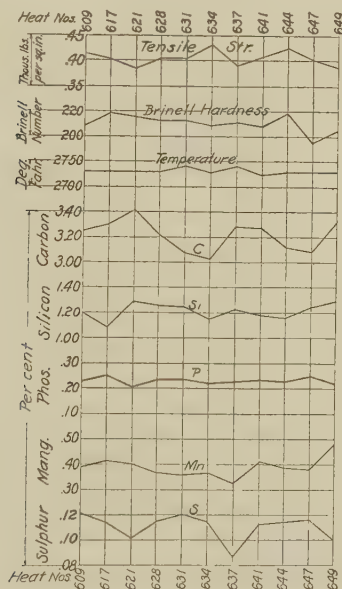


FIG. 27—TABULATION OF QUALITIES OF IRON OF ELEVEN HEATS

This practice to the author's knowledge was adhered to for nearly five years after heat No. 30 was conducted. During that period an accurate record was made of every heat melted. Figs. 27 and 28 are portions of these records picked at random. Fig. 27 is a record of all heats melted in the 36 inch cupola between September 15, 1925, and October 30, 1925. Fig. 28 is a record of heats melted in the same cupola between December 28, 1925, and February 6, 1926. The temperature of melting was uniform throughout and the chemical composition within the limits anticipated. However, there is one exception; the percentage of

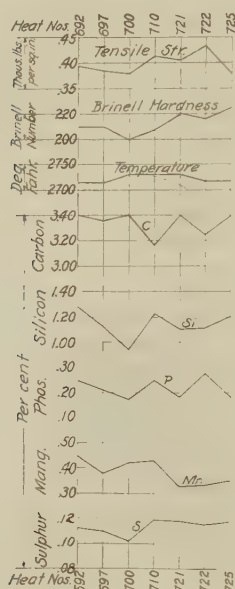


FIG. 28—TABULATION OF QUALITIES OF IRON FROM SEVEN HEATS

total carbon during the period covered by Fig. 28. On checking back it was found that the coke used during this period was about four per cent low in fixed carbon. As a result the average temperature was about 10 degrees Fahr. lower and the carbon an average of about 0.10 per cent higher than during the period covered by Fig. 27.

Strength of Iron Can Be Increased by Control of Cupola

By careful analysis and control of cupola operation, it was possible to improve the tensile strength nearly 30 per cent from 28,000 to 30,000 to a range of 37,000 to 40,000 pounds per square inch, and maintain the Brinell hardness between 200 and 220. In fact, the quality of the metal was improved to such an extent that the shelf stock of spare Diesel engine parts for submarine service was reduced to one-third of the previous amount because of longer service obtained in operation. This fact clearly demonstrates that precise cupola control is an economically sound proposition.

The Use of Scrap in Gray Iron, Malleable, and Electric Steel Mixtures

BY E. K. SMITH* AND F. B. RIGGAN,* BIRMINGHAM, ALA.

Changing conditions bring new problems, which have to be met in one way or another; and the use of scrap in mixtures is a problem which confronts every iron and steel foundry today. Every furnace has to consume a proportion of scrap, ranging from a moderate amount of remelted gates, etc., up to the 100 per cent scrap mixture sometimes used. And everywhere, closely connected with the scrap question, is one of greater importance—How to maintain a steady improvement in the quality of the manufactured product? We are all familiar with the striking betterment in the characteristics of malleable castings during the past ten or fifteen years, and with the remarkable results in the steel casting field. More recently, the metallurgy of gray iron has been studied, both from practical and theoretical sides, and great improvements have resulted.

Use of Scrap and Quality of Product

The use of all kinds of scrap, whether foundry gates, or bought material, requires more care than does the melting of pig iron, but it is an interesting fact that many of the improvements

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Discussion of this paper begins on page 619.

in quality have been accompanied by carefully regulated use of scrap in the mixtures. A classic example of this is David McLain's advocacy of the use of steel in cupola mixtures. More lately the German Lanz and Emmel-Thyssen pearlitic gray irons have been brought forward, together with several patented products, most of which have very considerable merit. And almost without exception, these improved irons depend to a great extent on the use of scrap in their mixtures, particularly steel scrap.

During recent years, engineers have demanded stronger and more uniform metals. At first the foundries asked for better pig iron, but the best of pig would not give much more strength. Then they looked to their melting equipment, and made some decided improvements, but still without any great increase in the strength of their product. Finally, the use of steel and other scrap in their mixtures was turned to, but with considerable reluctance, as most foundrymen can recall some disastrous experiments with the use of scrap. Either the sulphur gradually got too high, or the castings had blow-holes, or the iron "had no life" or some other serious trouble plagued them, until they went back to a straight pig iron mixture. (It is well to keep in mind that poor scrap, or good scrap wrongly used, can cause every kind of foundry trouble.)

After some years of work, here and abroad, rules and precautions for melting scrap have been worked out, so that today metal can be regularly produced with physical properties far surpassing the old standards.

When using considerable proportions of low carbon material in any mixture, it is of course absolutely essential that furnace conditions be first class, that all charges be weighed, and that melting conditions are as nearly standardized as is possible.

In the past, varying amounts of cheap scrap were thrown into the mixture by some foundries, for the sole purpose of reducing costs—with disastrous results. Today, the maintenance of quality often calls for the use of scrap, while the saving in mixture costs is small, owing to the slight difference between the price of good scrap and pig iron. The first thing to know is, what is the best metal for the desired casting; then what type and proportion of certain raw materials will give the required results.

Economic Situation

Charles P. Perin¹ stated that there are known iron ore deposits amounting to 33,000,000,000 tons, and 99,342,000,000 tons possible deposits. He figured that in 76 years all known ore will be gone. He stated also the well known fact, that cheap iron is absolutely essential to our civilization. It would be difficult to imagine the state of civilization, if it were not for that most important property of iron—namely magnetism.

We must use scrap, whether we want to or not. The salvage of iron material is inevitable—it is an economic necessity. Fletcher² says: "To each country whose interest in ferrous metallurgy is vital, the scrap problem becomes one of national importance."

The total ferrous scrap produced in this country is stated to be about 20,000,000 tons yearly. As every ton of scrap saves two tons of ore the use of scrap in this country alone saves yearly 40,000,000 tons of our diminishing ore reserves.

The amount of scrap produced is continually increasing. Engines, pipe, automobiles and other equipment are continually being replaced by more modern machines. In the automotive field alone, about a million cars are scrapped yearly, with an average of about a ton of metal in each.

This great supply of raw materials would be available for foundry use, if it could be had in suitable form.

Sorting of Scrap

In order to use scrap safely in the foundry, it is absolutely necessary to have it properly sorted. The railroads have done pioneer work on the salvage of scrap. Cars of sorted cast scrap, and of short rails, have established a standard for the whole market.

The several scrap associations are carrying on this work. The scrap now available is far better than that of ten years ago, and there is yet room for improvement. Fletcher, in his A. F. A. (1925) exchange paper, states: "The disposal of scrap cannot

¹ *Iron Trade Review*, p. 1568, Dec. 11, 1924.

² *Transactions A. F. A.*; Vol. 33, p. 31, 1925.

be allowed to remain in the hands of distributors who are careless and often ignorant of the scientific importance of the problem."³

Mixed scrap is a constant source of trouble. There is no economy in using poorly sorted scrap, no matter what the price, for difficulties are sure to follow. More and more iron products are being sold under specifications, and it is only under specification that the scrap metal industry will come to its own.

Specifications

During past years, several sets of specifications have been drawn up by purchasing agents, by railroads, and by scrap dealers. All this has been a step in the direction of better scrap, but many dealers have not been in favor of these varied specifications, so their use has been limited.

For the good of the scrap industry, a general specification is absolutely necessary. Such a specification has been drawn up by meeting of "producers, dealers, consumers, and Government agencies," and is embodied in "Classification of Iron and Steel Scrap"⁴ issued by the Department of Commerce, Bureau of Standards.

We believe that this classification of scrap is a very great step towards the safe use of waste metals, and that the sooner it is generally adopted throughout the country, the better it will be for the scrap industry, and for the iron and steel trade in general. Space does not permit consideration of this specification in detail. It may be sufficient to state that it covers in every particular, the requirements of blast furnace, acid and basic open hearth, electric furnace, gray iron, and converter. It covers the disposal of practically every kind of scrap which the dealer may have to handle, including borings and turnings, burned iron, scale, old annealing pots, etc., as well as the standard grades, sorted according to size and weight.

To illustrate the need for such general specifications, it may be well to mention some specific instances. A car of cast scrap

³ Transactions A. F. A.; Vol. 33, p. 30, 1925.

⁴ This may be obtained by sending ten cents to the Supt. of Documents, Washington, D. C., U. S. Printing Office, asking for Simplified Practice Recommendations R 58-28.

arrived, the great bulk of which consisted of broken heavy machinery, the pieces averaging about 250 pounds each. The local specification called for nothing over 150 pounds. On investigation it appeared that the car had been bought on the local specification of 150 pounds, but as the dealer was short of this grade, he bought a car from a neighboring city, where 250 pounds was accepted as Number 1 Cast. This car had to be rejected and reconsigned, with a loss for all concerned. A generally accepted specification would have prevented this.

A case where the railroad specification saved an argument came up when a carload of all steel angles was received, and on examination was found to contain a good deal of old high phosphorus wrought iron. The dealer and railroad inspector examined the material, and reconsigned it without argument, which would not have been the case had there been no specification.

One important point, which is often neglected, is for the purchasing agent to hold the dealer strictly to any specification that has been agreed on. In one case the purchasing agent permitted the dealer to ship two car wheels in a car of cast scrap. The next car contained six wheels, and the third car thirty-six wheels.

A good way to handle carloads containing a few pieces of poor material, is to lay the worst to one side, and insist on the dealer coming to inspect them. This does not cause him any financial loss, but in a short time the word penetrates his yard that poor material will not be accepted—and quality improves.

Manlove⁵ suggests the employment of impartial weighers and inspectors of scrap. If not too expensive, such a system would result in far better scrap sorting, and would be of especial benefit to the small foundry.

Scrap for Gray Iron Mixtures

The gray iron foundryman has a wide field of scrap to choose from, much of which can be used to benefit his mixture. Some of the common grades are considered below.

⁵*Scrap Metals*, Manlove and Vickers; Penton Publishing Co., Cleveland.

Steel—Usual analysis: Silicon 0.05 per cent, Sulphur 0.04 per cent, Phosphorus 0.04 per cent, Carbon 0.20 per cent. Melting of steel resolves itself into having proper cupola practice, and good steel. The bed must not be very low and sufficient coke must be used for superheat (7 to 1 is a common ratio). Much trouble comes from use of steel which is too thin or too thick. Table 1 gives a possible guide for steel on various sized cupolas.

Table 1
STEEL SCRAP

Diam. Cupola Inside Lining, Inches	Thickness, Inches		Maximum Length, Inches	Maximum Weight, Pounds
	Maximum	Minimum		
48	1	$\frac{1}{4}$	24	50
60	2	$\frac{1}{4}$	36	75
72	3	$\frac{1}{4}$	48	100
90	4	$\frac{1}{4}$	60	150

Malleable Scrap—Usual analysis: Silicon 0.75 per cent, Manganese 0.30 per cent, Sulphur 0.090 per cent, Phosphorus 0.15 per cent, Carbon 2.00 per cent. This material is not popular in the gray iron foundry, mainly because of its high sulphur, and because the agricultural grades are often badly rusted.

Cast Scrap.—This is used mainly to cheapen mixture. Table 2 shows approximate limits of scrap for various sized cupolas.

Table 2
CAST SCRAP SIZES FOR CUPOLAS

Diam. Cupola Inside Lining, Inches	Thickness, Inches		Maximum Length, Inches	Maximum Weight, Pounds
	Maximum	Minimum		
48	4	$\frac{1}{4}$	24	100
60	6	$\frac{1}{4}$	36	150
72	6	$\frac{1}{4}$	48	150
90	8	$\frac{1}{4}$	60	200

Table 3 gives some analyses of common grades of cast scrap. Carload lots of the various kinds usually analyze fairly near these figures.

Table 3
ANALYSES OF SOME COMMON GRADES OF CAST SCRAP

	Silicon	Sulphur	Manganese	Phos.	Carbon
Machinery	2.00	.090	0.80	0.60	3.50
Railroad	2.00	.090	0.80	0.50	3.25
Agricultural	2.25	.090	0.70	0.70	3.50
Stove Plate	2.50	.070	0.55	0.95	3.75
Car Wheel	0.65	.080	0.50	0.35	3.50

Another item to be disposed of is gangway shot, and screenings. When these are less than $\frac{1}{4}$ inch in size, it is often cheaper

to sell to a dealer for blast furnace use, than to risk getting dirty, or oxidized metal.

All the usual precautions of cupola practice apply doubly when using much scrap in mixture. In particular:

1. Use no poor scrap of any kind, especially oversize or thin.
2. Use no very dirty or rusty scrap.
3. Break up all flat plates which might obstruct blast.
4. Every charge level—and covered with coke.
5. Keep slag liquid—use flux if necessary.
6. Charge steel first, then pig, then scrap.
7. If a large lump of scrap must be melted, place enough coke under it, so that it will not sink down into bed coke.
8. If melting whole motor blocks, be sure to allow for the steel they contain.

A typical four cylinder complete motor contained:

Cast iron.....	149 pounds
Steel	57 pounds
Brass	1.6 pounds
Babbitt	1.2 pounds

Experimental Mixtures

Varying Percentages of Scrap

In order to get a comparison between mixtures with varying amounts of scrap a series of charges was run, with scrap varying from 25 to 100 per cent, balance being pig iron—silicon 2.25 per cent. The scrap in each charge consisted of equal parts of automobile, pipe and radiator. The results are given in Table 4.

Table 4
VARIATION OF ANALYSIS WITH VARYING SCRAP PER CENTS

	25% Scrap	50% Scrap	75% Scrap	100% Scrap
Silicon	1.50	1.44	1.80	1.90
Sulphur	0.090	0.128	0.130	0.140
Manganese	0.400	0.540	0.500	0.440
Phosphorus	0.73	0.76	0.72	0.68
Combined Carbon	0.89	1.06	0.86	1.15
Graphite	2.35	2.45	2.65	2.40
Total Carbon	3.24	3.51	3.51	3.55
Brinell	207	212	207	223
Transverse Strength	3400	3700	3900	3750
Tensile	29900	33100	28400	28000

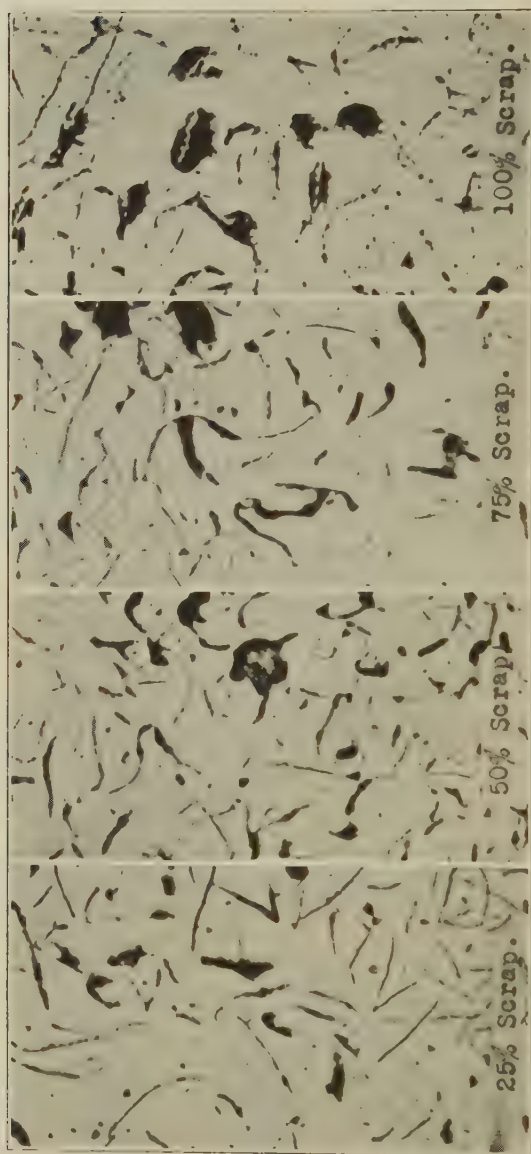


FIG. 1—UNETCHED MICROGRAPHS OF IRONS WITH VARYING PER CENTS OF SCRAP TO SHOW INCLUSIONS OR LACK OF INCLUSIONS—100 X—UNETCHED

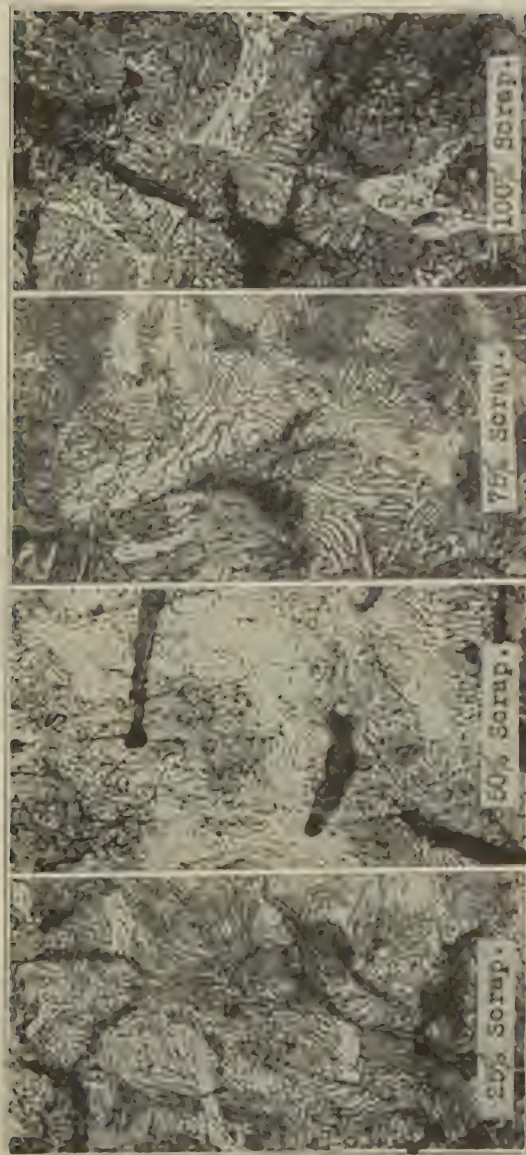


FIG. 2—ETCHED MICROGRAPHS OF IRONS WITH VARYING PER CENTS OF SCRAP—SAME IRONS AS IN FIG. 1
500 X—ETCHED WITH SOLUTION NITRIC ACID AND ALCOHOL

The unetched micrographs of Fig. 1 show no difference in structure through mixtures with 75 per cent scrap, but in all-scrap mixtures there appear to be some inclusions, possible oxides, and grain is finer. Etched samples of Fig. 2 show little change until 100 per cent scrap is reached. Increasing amounts of scrap in mixture had little effect on physical properties, and but little on analysis, except to raise sulphur. Hardness increased slightly with increased scrap.

This series of experiments tends to show that the proportion of scrap in the mixture does not have much effect on physical properties on the first melt, regardless of what raw materials went into the mixture. It must be kept in mind that such high percentages of scrap would be impossible for most actual foundry mixtures, as the return scrap would shortly raise sulphur above the danger point, unless this was removed in some way.

Effects of Borings, Tin, Zinc and Burned Material

In order to find the exaggerated effect of borings, tin, zinc, and burned material, we ran the experimental heats of Table 5.

Table 5

Contents of Charges	No. 1 All Burned Material	No. 2 All Borings	No. 3 All Scrap, 5% Tin	No. 4 All Scrap, 5% Zinc
Silicon	1.69	1.80	1.45	1.90
Sulphur	0.115	0.147	0.092	0.098
Manganese	0.27	0.27	0.32	0.33
Phosphorus	0.714	0.708	0.462	0.520
Total Carbon	3.03	3.00	3.40	3.54
Graphite	1.95	1.80	2.40	2.85
Combined Carbon	1.08	1.20	1.00	0.69
Brinell Hardness	228	241	228	179
Tensile Strength, lbs. per sq. in....	22000	22200	25700	27800
Transverse Strength, pounds....	4200	2200	2350	2500

Micrographs (Fig. 3) of castings melted from burned material show a large number of small inclusions, although physical properties were not very bad. These small inclusions are invariably a sign of poor iron, together with the lowered carbon and manganese indicating oxidized metal. No burned material should be used in any foundry mixture, it being only suitable for blast furnace use.

Micrographs of bars melted from all borings show a large number of small inclusions, similar to the burned material, but worse. This simply confirms practical experience with the use

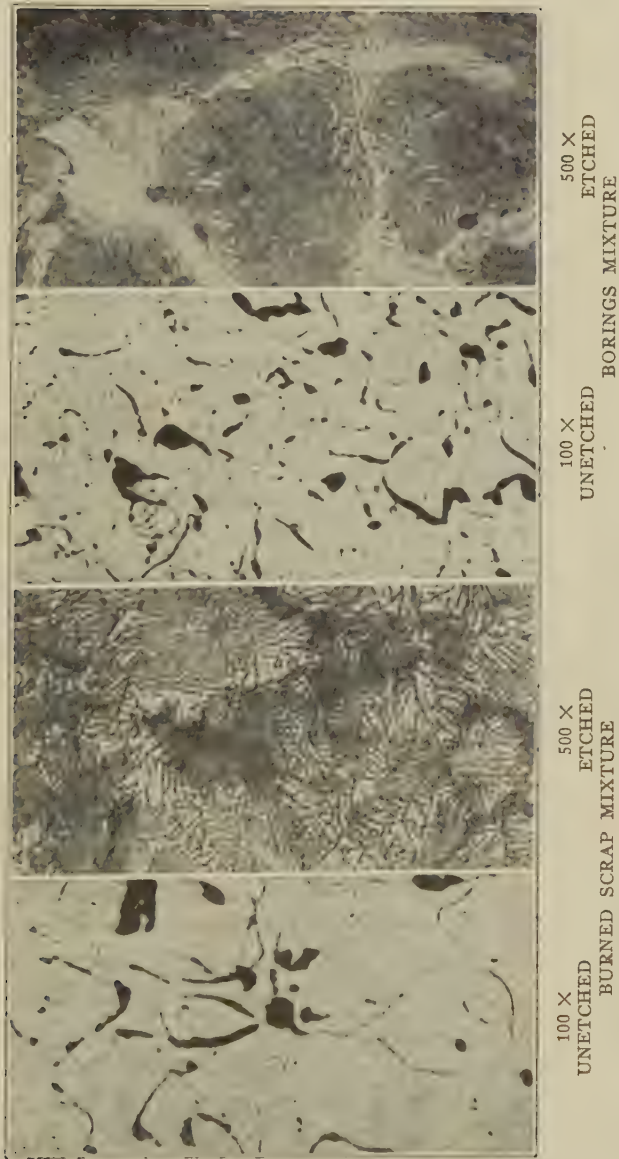


FIG. 3—UNETCHED AND ETCHED IRONS FROM BURNED SCRAP

of borings, which are produced in large quantities in many shops. Some cases are reported where borings are successfully charged in wood or metal containers, but the general experience shows that melting of borings in the cupola invariably results in trouble, mostly from shrinks, "dead iron" and other manifestations due to oxidized metal. There are a number of cases where borings have been compressed by very high pressures into briquettes, which are almost as solid as pig iron, and which are said not to cause oxidation. The place for borings is the blast furnace or electric furnace.

The object of mixtures containing tin and zinc, was to determine whether a small amount of tinned or galvanized scrap, such as is frequently received, would have any possible detrimental effect on gray iron, under usual conditions. In order to make the conditions extreme, the mixtures were 100 per cent scrap gray iron, and both tin and zinc were added in ladle, as well as in charge. In spite of these conditions, little effect was found on analysis, or on physical properties. Micrographs (not reproduced) showed typical fractures, with no sign of inclusions. In ordinary practice, the zinc probably volatilizes before it reaches the melting zone. It seems very probable that tinned, or galvanized materials, in any ordinary amounts, would have no effect on quality of cast iron.

Typical Scrap Mixtures—Gray Iron

In considering any scrap mixtures, one point cannot be over-emphasized—provision must be made for mixing the iron as it melts. Where the cupola is tapped out periodically, the crucible should hold at least a charge. If a mixing ladle is used, with continuous pour, the ladle should hold at least a charge. Larger ladles mix better, but too much heat is lost.

In gray iron mixtures, a wide range of scrap is available, depending on the characteristics of the castings required. In a foundry producing 30 per cent scrap to be remelted, the old method was to add 70 per cent of suitable pig iron, the resulting casting having open grain, and moderate strength. Under present

conditions, a stronger, closer grained iron could be obtained, at slightly lower cost by the charge shown below:

Remelt	30 per cent
Pig	50 per cent
No. 1 Cast Scrap.....	15 per cent
Steel Scrap.....	5 per cent

This gives fluid iron with physical properties of 28,000 pounds per square inch tensile strength and 3,400 pounds per square inch transverse strength.

Meissner⁶ reports similar results using a regular mixture with no steel, giving tensile 21,000 pounds with transverse 2,200 pounds. A different mixture, containing 20 per cent steel, gave: Tensile 41,500 pounds and transverse 4,400 pounds.

Most of the high test cast irons depend on the use of steel scrap, which has a decidedly beneficial effect on strength. A great part of this is due to the reduction in carbon and phosphorus. Steel picks up from 2.75 to 3.00 per cent carbon in melting, reducing carbon in the casting accordingly. Its use gives a better iron with closer grain—or smaller flakes of graphite. Hurst quotes Wheeler⁷ as stating that tensile strength increases 2,000 pounds per square inch for each 5 per cent of steel added. Steel in the mixture strengthens iron in two ways—by reducing carbon, and by producing higher temperatures, with resulting good effects.⁸

Steel can be melted in the cupola in any proportion up to 100 per cent, methods of procedure being well known.⁹

An ordinary mixture for all-steel melting is given by Hudson,¹⁰ with steel 2,240 pounds, ferro-manganese (80 per cent) 16 pounds, ferro-silicon (50 per cent) 60 pounds.

Scrap in Malleable Mixtures

Scrap available for malleable practice, either air furnace or cupola, is limited practically to two items—steel and malleable scrap.

⁶ *Foundry*, p. 229, March 15, 1928.

⁷ *Foundry Trade Journal*, p. 257, March 24, 1927.

⁸ Piwowarsky, *Stahl und Eisen*, 1927.

⁹ A. F. A. Transactions; Jennings; Vol. 34, p. 1011, 1926.

¹⁰ *Foundry*, p. 857, Nov. 1, 1926.

Steel: Steel should be not thinner than $\frac{1}{4}$ inch and should be free from castings and forgings, owing to possibility of contamination from alloys. Most of the alloys have a marked effect on a malleable anneal, either accelerating or retarding graphitization. Probably the most feared is chromium, a very small percentage of which will completely prevent the malleable anneal. The importance of avoiding alloys cannot be overestimated. For this reason, such scrap as steel rails, "3 ft. and under," and short "I" beams, crop ends, etc., are preferred.

Even when using steel rails there is danger of alloys; chromium is sometimes found. Switch points and cross-overs of manganese steel may get in rail scrap. These may contain 15 per cent manganese and would cause very high manganese in castings.

Light or rusty steel is unsuitable for malleable use owing to oxidation.

In the cupola, large steel plates should not be used as they obstruct the blast, and cause "hang-ups." Punchings are bad, as they drift down between charges and cause erratic melt.

In using any scrap care must be taken not to include cast iron as the high phosphorus would cause trouble in galvanizing or anneal.

Malleable: Malleable scrap may be safely melted in air furnace or cupola but if any large proportion is used, desulphurization with soda ash will probably be necessary. Agricultural scrap is often too rusty for safe use and in spite of its lower price is no economy, unless it can be inspected prior to purchase.

Railroad malleable is usually of uniform size, and not too rusty and commands a good price.

One precaution to be especially observed in using malleable scrap, is to look for castings which are made of gray iron and steel as well as malleable. Grease boxes are made in both malleable and cast iron. When malleable scrap comes direct from the railroad yard, the sorting is accurate, but often cars are bought and scrapped by local yards, in which case a number of gray iron boxes may be mixed with the malleable, which might cause serious trouble. As a rule the gray iron castings can be

separated by inspection as they have a heavier section than the malleable.

Sprues must be remelted and are much better if rolled free from sand. They should be melted each day.

Buying a carload of scrap used to be a gamble, as almost any analysis could be found in the castings. Today most of the malleable is made according to uniform practice and practically all malleable scrap has a similar analysis.

In the air furnace, malleable scrap can be used in moderate amounts, but the percentage of sulphur in the castings must be closely watched. Steel can be used only in small amounts as carbon would be too low, unless the metal is to be recarburized. Rusty scrap will reduce silicon and manganese. A typical malleable air furnace mixture follows:

<i>Material</i>	<i>Per Cent</i>
Sprues	45
Pig	40
Malleable Scrap.....	10
Steel Scrap.....	5

Scrap for cupola malleable must have the same characteristics as for the air furnace. Cupola mixtures are flexible as the steel takes up about 2.7 per cent carbon from the coke. During the past ten years the quality of both air furnace and cupola malleable has shown a great increase, in strength and reliability. Today, uniform high test malleable is being made both in air furnace and cupola.

Owing to the close limits, great care must be taken in choosing scrap for malleable mixtures. Every carload should be inspected and analyzed.

Scrap for Electric Steel Mixtures

Steel scrap is the basis for all electric steel mixtures.

The acid process requires very high grade scrap. It must be of small size, to get in the furnace door, and must not be too heavy for a man to handle. Sulphur and phosphorus should be slightly lower than is required in the castings; usually both should be under 0.04 per cent.

It is convenient to have a pile of high carbon scrap, such as springs with about 1.00 per cent carbon, as the bulk of the scrap will be low carbon—about 0.20 per cent.

In the acid process the steel scrap must not be too rusty. Material under $\frac{1}{4}$ inch in thickness is likely to be badly rusted, and will be too bulky to get much weight in the furnace.

Steel scrap for the basic electric process is more easily obtained. A little rust does no harm and sulphur and phosphorus do not have to be kept to such low limits in the scrap, as both of these are greatly reduced in this process.

Both electric furnaces use punchings, clippings, bar ends, heavy turnings, etc. Light turnings sometimes give trouble.

The use of scrap containing alloys depends on whether these would be objectionable in the castings.

Scrap for Electric Gray Iron

The electric furnace is suited for melting gray iron borings, and other low priced materials, from which high test gray iron can be produced by the addition of ferro-silicon and ferro-manganese.¹¹

In certain parts of the country scrap is available in large quantities, but pig iron is very costly. In such locations, scrap and borings can readily be used for the electric production of gray iron.

The electric furnace will show development where power costs are low, and by desulphurizing will make first class castings out of otherwise useless material.

Desulphurization in Relation to Scrap Use

The economic situation of Germany forced the use of large quantities of scrap in her furnaces, with the usual effect—that sulphur began to increase. A solution of this problem was effected by the well known work of Dr. Walter on alkaline slags.

Several years ago the alkaline processes were introduced in this country, and are widely used at present. There seems to be some disagreement as to all the reactions, but in general,

¹¹*Iron Age*, p. 1359, Nov. 29, 1928.

sodium carbonate is placed in contact with molten iron, the carbonate decomposing at this temperature. The sodium combines with the sulphur in the iron, forming sodium sulphide, which remains in the slag.

As a rule the fused form of sodium carbonate is used as it comes in small bricks, which are easy to handle. (The powdered form is sometimes used in closed containers.) Each brick weighs two pounds and the required number is thrown on each charge with the limerock, in the cupola. The main effect is to make a more fluid slag, which helps clean the scrap as it approaches the melting zone. Apparently the alkaline slag reacts with oxides in the charge, and at same time reduces the amount of sulphur absorbed by the iron.

Final desulphurization takes place after the iron has run from cupola, and has been separated from the cupola slag. For this final slag soda ash is used, either on a mixing ladle or in a forehearth. The slag usually absorbs from 10 to 50 per cent of the sulphur present, according to amount of soda ash used and time it is in contact with iron.

Results reported on malleable air furnace practice and on open hearth indicate a reduction of sulphur and possible absorption of included oxides.

As a check on structure of desulphurized, and untreated irons, two experimental heats were run using all scrap mixtures of practically identical composition. Results are given in Table 6.

Table 6
EFFECT OF SODA ASH ON ALL SCRAP MIXTURES

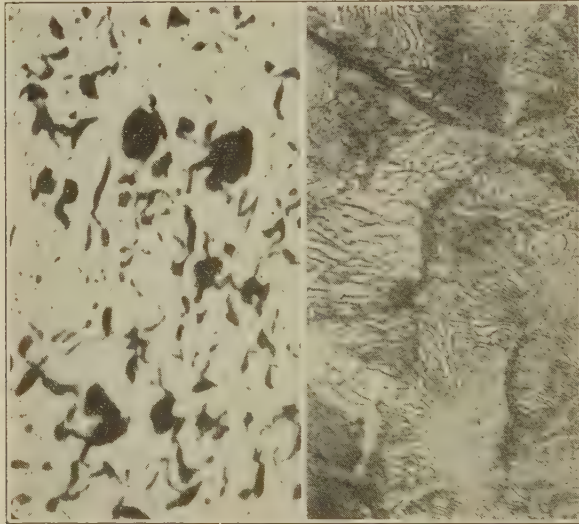
<i>Desulphurized</i>	<i>Not Desulphurized</i>
Silicon, per cent 1.45	Silicon, per cent 1.90
Sulphur, per cent 070	Sulphur, per cent 140
Manganese, per cent 30	Manganese, per cent 44
Phosphorus, per cent 50	Phosphorus, per cent 68
Carbon, per cent 3.20	Carbon, per cent 3.55
Brinell Hardness No. 196	Brinell Hardness No. 223
Pounds Transverse Strength.....3,900	Pounds Transverse Strength 3,750
Tensile Strength, lbs. per sq. in....34,000	Tensile Strength, lbs. per sq. in....28,000

The former heat with great excess of soda ash showed 50 per cent reduction in sulphur, with probable reduction of silicon.

Microphotographs of Fig. 4 show normal structure, unetched, and etched. There are less inclusions than might be expected

with 100 per cent scrap mixture, so there is a strong probability that the alkaline slag removes inclusions to some extent, in the process of desulphurization.

As it is imperative to keep sulphur content of any mixture under control, some process of desulphurization must be used, if the mixture carries much high sulphur scrap. For this purpose,



100 X UNETCHED

500 X ETCHED

FIG. 4—DESULPHURIZED ALL SCRAP MIXTURES

the soda ash process has advantages, as shown above. Sulphur can be even more completely removed in the basic electric furnace process, by absorption in slag.

Some sulphur can also be removed by means of manganese.

Other Uses of Scrap

Probably 75 per cent of all steel scrap is remelted in the open hearth, acid and basic.

Besides the open hearth, one of the greatest outlets for scrap today is the blast furnace. The growing use of scrap in furnaces is the subject of much discussion at present, some feeling strongly that use of borings, cast and steel scrap in the blast furnace is

very detrimental to the quality of our pig iron, while others believe that such practice is economical and harmless.

Obviously the same precautions would hold in blast furnace mixtures as elsewhere. For instance, if malleable pig is to be made, alloy steel scrap should not be used in burden.

Borings, turnings, sheet and detinned metals, old annealing pots and other burned scrap, have no place in foundry mixtures, yet must be used somewhere. It is difficult to believe that a small proportion of such materials, or of cast or steel scrap, in the blast furnace, can have a very detrimental effect on the quality of the resulting pig, provided, of course, that the furnace is operating correctly.

Another growing outlet for scrap is in duplexing, either with cupola and electric furnace or air furnace, or with direct metal from the blast furnace, with cupola and electric furnace. The processes of the Ford Motor Company offer a very efficient use of such scrap materials.¹²

Conclusions

A Harvard economist stated: "Agriculture spends only its interest, while the metal industry is living on its principal." As the farmer has been compelled to enrich his soil in order to conserve its resources, so the metal industry is being compelled to use all its waste materials in order to conserve a vanishing ore supply.

The scrap industry has made rapid progress in getting nationally organized. The co-operation between purchasing agents, the scrap metal dealers, and the Department of Commerce, has resulted in specifications suited to all types of furnaces, and all grades of scrap.

To keep in step with improved quality, both the processes and the selection of materials must be under closer control. The scrap yard of the future will probably be equipped with briquette machines, balers, furnaces, magnetic separators, and even chemical laboratory.

¹²*Foundry*, p. 710, Sept. 15, 1927.

It is an individual problem for each foundry to decide what kind of scrap it can use—and how much of it. The answer will depend on the kind of scrap available, its cost, the melting process involved, and the class of work produced. In some cases, such as the electric furnace, all-scrap mixtures are justified. In most cases, relatively small amounts of scrap may be used, with improvement in quality and some saving in cost. There is a place where each kind of scrap metal can be used to advantage, whether it be in the air furnace, cupola, electric or blast furnace.

An Analysis of the Performance of Fifty-Four Inch Cupolas Based Upon Records of Practical Operation

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Introduction

While the cupola is the most efficient of metallurgical furnaces, it is well-known that it is unusual to find one which is operated to anything like the best possible advantage. A large number of papers on cupola practice have appeared in the literature in which this fact has been pointed out. In THE FOUNDRY in 1920 appeared a report of a survey made to determine the extent of the wastage of foundry coke.¹ It was shown very definitely that in most cases much more coke than necessary was being used. Unfortunately, the average cupola operator does not regard the efficiency of the furnace as a very important consideration so long as he succeeds in obtaining molten iron at the temperature he desires. Moreover, in many parts of the country, coke is cheap and it seems more economical to overlook efficiency of operation than to attempt to save coke. It is well-known, however, that when excessive coke is used, the quality of the metal is apt to be lowered by virtue of the increased carbon and sulphur absorption, and it would seem for

*Director, Division of Foundry Research, Whiting Corp., Harvey, Ill.

¹P. Dwyer, The Foundry Vol. 48, pp. 670-8 (1920).

Discussion of this paper begins on page 678.

this reason, if not for purposes of economy that careful attention should be given to the problem.

It has also been found that too little attention is ordinarily given to the air supply of the cupola and consequently either too much or too little is introduced for perfect combustion. This results in economic loss because with too little air the coke is only partially consumed and with too much the coke burns too fast and the excess air oxidizes the iron.

In some foundries the cupola is operated without blast meter or pressure gauge with the result that the operator has no means of determining intelligently the conditions existing in the cupola except for the temperature of the iron pouring from the spout, and the nature of the flame at the charging door. Too often in this case, the operator depends upon his eye, and although he is generally correct in his estimate of the temperature, it would be preferable to use a standard optical pyrometer. If the latter is used accurate records can be kept which are not possible the other way. Every cupola should be equipped with an instrument for measuring the volume of air supplied, and a gauge indicating the pressure in the wind box. In some very well-regulated foundries recording instruments are used.

Many writers have advocated the periodic analysis of the stack gases as an indication of the combustion conditions. This is a troublesome operation requiring considerable skill on the part of the sampler and the analyst, and such analyses are made in relatively few foundries. Most of the records of this kind which are available in the literature have resulted from carefully planned and executed experimental heats. As a matter of fact, it is possible by the use of suitable indicating or recording instruments in regulating the air supply to attain combustion conditions which approximate the ideal.

In order to determine as exactly as possible the conditions surrounding actual practical cupola operation, a very comprehensive questionnaire was sent to 136 representative concerns operating cupolas with the request that information, as complete as possible, be supplied. The response was quite satisfactory, and a considerable amount of material has been made available for analysis.

The comprehensive nature of the replies to the questionnaire was such that some difficulty was experienced in deciding how the analysis should be conducted. It was finally decided to approach the problem from the standpoint of thermal efficiency, that is, the ratio of the heat evolved from the combustion of the coke to the heat utilized in melting iron. It was thought that actual heat balances in which the heat used in melting slag, heating up the lining, and that carried off in the stack gases were unnecessary since an approximation can easily be made which will furnish the desired basis of comparison. Moreover, the calculation of heat balances is a highly technical procedure, and one of the objects of this work is to develop a method for obtaining an approximate value for the efficiency of the cupola operation which can be used by the cupola operator himself without the use of elaborate calorimetric equipment or the need for any special technical knowledge.

It is usual for cupola operators to confine their attention to the melting ratio as a measure of efficiency, but on this basis, obviously it is impossible accurately to compare two cupolas because of the possible difference in the carbon content of the coke and the volume of air used for combustion. In working out the basis for the calculation of thermal efficiency the actual fuel consumption in terms of carbon was used.

It was noted from the questionnaire data that some cupolas are lined straight and others are contracted in diameter from some point below the charging doors to the top of the tuyeres. The latter are said to be boshed at the melting zone. In the course of the investigation the question has arisen as to the effect of the bosh on the thermal efficiency and the melting rate. Therefore, for a given size of cupolas, two classes are assumed to exist, the straight-lined and the boshed, and the summaries have been made accordingly. The value of a second row of tuyeres can also be given some consideration in the comparison.

While all the data desired have not yet been made available, there is sufficient information at hand to warrant a comparison of cupolas lined to 54 inches inside diameter on the basis of the calculation already referred to. The general operating results of eight cupolas each of the types under consideration have been tabulated and compared. It is to be noted that the study of

Table 1
PERFORMANCE OF CUPOLAS STRAIGHT-LINED TO 54 INCHES

Questionnaire No.:	6	16-B	19	21-A	21-B	37	45-B	50	Average
Iron Melted, tons	Sanitary	Seating	Lt. & Med. Machine	Mach. Tools	Mach. Tools	Pipe Fittings	Heating Boilers	General	
Melting Period, hours	60.0	21.1	19.5	25.0	25.0	28.5	30.45	90.0	...
Melting Rate, tons per hour	9	1.67	2	2.25	25.0	3	3	8	...
Temp. of Iron, deg. Fahr.	6.67	12.67	9.75	11.10	2.25	3	3	11.25	10.27
Bed Coke, pounds	2700	2800	2850	2600	2600	2650	2700*	2500	...
Charge Coke, pounds	1430	1500	1480	2200	2200	1200	1825	4500	2042
Coke in Drop, pounds	15,600	4140	4330	5000	5000	8700	7975	20,948	...
Total Coke, pounds	17,030	700	1000	100	100	800	100	25,428	...
Coke Consumption, pounds per hour	1892	2960	4810	7100	7100	9100	9700	3180	...
Carbon in Coke, per cent.	90.0*	91.50	90.00*	88.75	88.75	88.60	90.00*	3180	...
Carbon Consumption, pounds per hour	1703	2715	2160	2800	2800	2690	2905	2860	...
Coke per Ton of Iron Melted, pounds	284	234	247	284	284	319	318	283	...
Carbon per Ton of Iron Melted, pounds	216	215	222	252	252	283	286	254	...
Iron Melted per Lb. of Carbon Consumed, lbs.	9.26	9.30	9.01	7.94	7.94	7.06	7.00	7.87	8.29
Blast Pressure, ounces	12-16	15	7-14	12	16	12	....	14-16	13.5
Blast Volume, cu. ft. per minute, ...	5000	5500	5200	6750	5389	6000	....	6000*	5700
Volume Air per Ton Iron Melted, cu. ft.	45,000	26,500	32,000	36,500	29,100	37,900	....	32,000	34,143
Volume Air per Lb. of Carbon Consumed, cu. ft.	208	123	144	145	115	134	....	126	142
Intermediate Coke Ratio	7.7	10.2	9.0	10.0	10.0	6.5	7.65	8.6	...
Total Coke Ratio	7.1	8.6	8.1	7.1	7.1	6.3	7.1	7.1	...
Thermal Efficiency, per cent	35.9	37.2	36.9	29.4	29.4	26.7	27.0	27.8†	31.3

*Assumed.

†Upper Tuyeres.

Table 2
PERFORMANCE OF CUPOLAS LINED TO 54 INCH AND BOSHED IN MELTING ZONE

Questionnaire No.:	2	15	24	44-B	44-C	58-B	59-B	66	Average
Type Casting:	Light	Automo-	Cylinders	Shock Ab-	Shock	Soil	Tractor	Pumps	
Minimum Diameter of Bosh, inches.....	44	50	42	sorbers	Absorbers	Fittings	48	50	46.5
Iron Melted, tons.....	34.3	50.0	80.0	44	44	39.25	58.0	50	....
Melting Period, hours.....	4.0	5.5	10.0	80.0	80.0	10.0	5.5	21.0	....
Melting Rate, tons per hour.....	8.58	9.09	8.00	10.0	10.0	4.36	10.52	2.25	....
Temp. of Iron, deg. Fahr.	2700*	2500	2800	2700	2700	2550	2500	9.34	8.26
Bed Coke, pounds.....	950	2310	1800	1700	1700	1725	2650	2750*	....
Charge Coke, pounds.....	7970	13,475	23,700	18,000	18,000	11,925	13,650	2300	1892
Coke in Drop, pounds.....	700	500	1500	500	500	600	1200	3850	....
Total Coke, pounds.....	8220	15,285	24,000	19,000	19,700	13,050	15,100	6150	....
Coke Consumption, pounds per hour.....	2055	2780	2400	1970	1970	1175	2745	2730	....
Carbon in Coke, per cent.....	90.0*	91.0	90.5	90.0	90.0	90.0*	90.0*	89.0	....
Carbon Consumption, pounds per hour.....	1848	2520	2170	1770	1770	1058	2470	2435	....
Coke per Ton of Iron Melted, pounds.....	240	306	300	246	246	270	261	292	....
Carbon per Ton of Iron Melted, pounds.....	216	278	272	222	222	242	234	260	....
Iron Melted per Lb. Carbon, pounds.....	9.26	7.15	7.35	9.00	9.00	8.26	8.55	7.69	8.28
Blast Pressure, ounces.....	10	10	10	12-14	12-14	....	12	12	11.4
Blast Volume, cu. ft. per minute.....	6168	6200	5000	6000	6000	....	4500	....	6311
Volume Air per Ton Iron, cu. ft.	43,200	40,900	37,500	45,000	45,000	....	25,600	....	39,530
Volume Air per Lb. Carbon, cu. ft.	200	147	138	202	202	....	110	....	166
Intermediate Coke Ratio.....	8.60	7.44	6.75	8.89	8.89	6.58	8.50	10.90	....
Total Coke Ratio.....	8.34	6.55	6.67	8.12	8.12	6.01	7.68	6.83	....
Thermal Efficiency, per cent.....	35.90†	25.40†	29.60†	34.80	34.80	29.90	33.00	30.20	31.70

* Assumed.

† Upper Tuyeres.

the data for only sixteen cupolas cannot lead to authoritative results, but it can point out the tendencies in any given direction.

Discussion of Results

Tables 1 and 2 show in detail the operating conditions of eight straight-lined and eight boshed cupolas in which gray cast iron for a variety of purposes is melted.

At the outset a question arose as to the correct method of expressing the output of the cupola. In the questionnaire the total weight of the iron charged was given and also the weight of the iron in the drop. In answer to the question as to the weight of iron melted, the same figure was usually given as that of the total iron charged. In some cases as much as 3,000 pounds of iron in the drop was reported, and unless the output is very large, this must be taken into account. It was decided to count this iron as not having entered the melting process at all and thus the weight of the iron actually melted has been taken as that of the total charge minus the weight of the iron in the drop. This necessarily affects the figures for the various items all along the line. The foundryman may consider such a quibble unimportant but if the melting efficiency is to be calculated with anything approximating accuracy, this correction should be considered. The question arises, of course, as to whether the iron in the drop is left unmelted or whether some of it has actually been in the molten state and subsequently cooled. The heat necessary for melting even this amount of iron should be considered, but since there is no way of knowing the conditions, it will have to be set aside and the results will be inexact to just that extent. In each case, therefore, where the figures have been given, the weight of iron melted has been taken as that of the total charge minus the drop.

The Effect of Boshed Linings on the Melting Rate

The melting period and the hourly melting rate need no explanation. The melting rate was recorded to determine the deviation from the normal melting rate as given by the manufacturers of cupolas. This figure for straight-lined cupolas of 54-inch diameter inside the lining is given as 10 to 12 tons. In Table 1

it is to be noted that the highest melting rate is 12.67 tons and the lowest 6.67 tons. The average, which actually means little because of the small number of data available, is 10.27 tons which is approximately the rate given by the manufacturers.

The melting rate of cupolas lined to 54 inches and then boshed to a smaller diameter in the melting zone is shown in Table 2 to be quite different. The highest rate recorded for this group was 10.52 tons for a cupola boshed to 48 inches minimum diameter and the lowest rate was 4.36 tons for a minimum bosh diameter of 50 inches. Obviously in the latter case the cupola was being purposely operated at a low capacity. The average rate for the eight cupolas was 8.26 tons and the average minimum diameter of the bosh was 46.5 inches. Attention is drawn to the fact that the cupola having the smallest bosh diameter (42 inches) showed a melting rate of 10 tons per hour.

While the question of the melting rate in the two types of cupola was under consideration, definite information concerning the location of the melting zone was sought. It was found in all cases that the melting zone lies within the bosh. The inference to be drawn then is that the melting rate should be referred to the smallest diameter of the cupola. If this is indeed true, the cupola with the 42-inch bosh showed a considerably higher melting rate than that given in the manufacturer's table for 42-inch straight-lined cupolas, that is, 6 to 7 tons per hour.

In general, however, it appears that the use of a boshed lining decreases the normal melting rate to that of a cupola straight-lined to the minimum diameter of the bosh. The lack of data available in this survey renders the drawing of an accurate conclusion impossible but the indication is well marked. This is borne out by the fact that in the case of cupola 59b, which is boshed to 48 inches, the melting rate shown is slightly higher than normal for a 48-inch straight-lined cupola.

The author holds the opinion that the presence of a bosh is advantageous from the standpoint of combustion conditions, which certainly have a bearing on the melting rate, but the data available are too meagre to prove or disprove the point.

The Temperature of the Molten Iron

The thermal efficiency of the cupola is markedly affected by the temperature at which the iron is delivered at the spout. Obviously, of two cupolas, each melting the same amount of iron by the combustion of the same amount of coke, that which produces iron at the higher temperature has made better use of the heat supply, and is, therefore, more efficient. In three of the sixteen cases no pyrometer was used and consequently the exact temperatures could not be recorded.

While the temperature of the iron at the spout is used in the calculations because it is easily measured, it is a fact that the temperature of the iron in the melting zone is much higher.¹ The efficiency calculated on this basis is, therefore, not the true efficiency but an apparent figure which is necessarily somewhat lower. However, since *comparisons* of performance are being sought, it is quite legitimate to use the temperature of the iron at the spout, and assume that the reduction in temperature due to the passage of the iron from the melting zone to the spout is a constant quantity.

Coke Consumption

The coke consumption is recorded in the tables in considerable detail. It will be noted that the amount of coke used for the bed varies considerably. In some cases a heavy bed charge is used and the first coke charge is considered to be included. In each case of this kind the weight of the first charge has been deducted from the weight of the bed coke, and the figures record the actual weight of coke used for the bed, thus being directly comparable. The variation is great—from 1,200 pounds to 4,500 pounds in the case of the straight-lined cupolas, and from 950 to 2,650 pounds in the case of the boshed cupolas. This variation is due to the fact that even though there is not much difference in the heights of the bed coke above the tuyeres, the tuyeres are set at different heights above the sand bottom and the bed coke capacity of the cupolas is different. The size of the coke is also a factor. It is plainly to be seen that there is no standard of practice in this respect. While the maximum and minimum

¹ Grennan, Foundry 51, 908-10 (1923).

figures are quite different for the two types of cupola, the average weight is only 50 pounds greater in the case of the straight-lined cupolas.

The variation in the weight of charge and total coke depend upon the melting period and the proportion of coke to iron melted. These figures must be reduced to a common factor before a comparison can be made. The first correction to be made is based on the carbon content of the coke which determines its value as a fuel. It would be preferable to know the actual heating value of the coke in British thermal units as determined by the use of the calorimeter, but in most foundries this is not carried out. The carbon content has not been stated in all the questionnaires, and where it has not, it has been assumed to be 90 per cent. It has also been assumed that none of the coke contains volatile matter, which introduces an error since most cokes contain 1 to 2 per cent which increases the heating value to some extent. It may be stated, however, that it is very doubtful whether the heat generated by the combustion of the small amount of volatile matter has any effect on the thermal efficiency because of the extremely short time it will remain in the cupola. As a basis of comparison in any case, the assumption is justified.

The hourly consumption of coke or carbon is of interest in indicating the difference in cupola operation, but it depends upon the amount of iron melted, and since this varies, no comparison is possible. It is necessary, therefore, to reduce this figure to the weight of carbon per ton or per pound of iron melted. Figures thus obtained are directly comparable, and the weight of iron melted by one pound of carbon is the *true melting ratio*. The latter means much more than the usual term "melting ratio" because in determining it, variations in the carbon content of the coke are taken into consideration.

From the data set forth in the tables it is found that in the case of the straight-lined cupolas the true melting ratio varies from 7.00 to 9.30 (pounds of iron melted per pound of carbon consumed), and the average is 8.29. For the boshed cupolas the variation is from 7.15 to 9.26, and the average 8.28. The indication is that boshing of the lining has no appreciable effect on the melting ratio.

Thermal Efficiency

The thermal efficiency of the cupola is after all the figure which is most desirable as a basis of comparison because it involves the coke consumption (on the basis of carbon content), the output of iron, and the temperature of the iron. A rather simple calculation is used in the determination of the thermal efficiency. The average melting point of gray cast iron is 2260 degrees Fahr. and the temperature at the spout varies from 2500 degrees to 2850 degrees as a rule, depending upon the type of castings produced. In order to calculate the quantity of heat necessary to melt the charge and superheat it to the pouring temperature, the specific heat of iron from 60 degrees Fahr. to 2260 degrees Fahr. is taken as 0.19, and from 2260 degrees Fahr. to 2850 degrees Fahr. as .023 B.t.u. per pound per degrees Fahrenheit. This is just another way of saying that relatively more heat is required to superheat iron than to melt it. The latent heat of fusion of iron is 41.5 B.t.u. per pound.

In explanation of the terms used in the preceding paragraph it must be stated that the specific heat of a substance is the amount of heat necessary to produce unit change in temperature of unit mass compared with water. The specific heat of water is roughly unity, which means that one heat unit is required to raise unit mass unit temperature. The units used in this country are the British thermal unit (heat necessary to increase the temperature of one pound of water one degree Fahrenheit), the pound, and the degree Fahrenheit. When the statement is made that the specific heat of gray cast iron from 60 to 2260 degrees Fahr. is 0.19, it means that within that temperature range 0.19 B.t.u. is required to increase the temperature of one pound of iron one degree Fahrenheit. In order to determine the total heat required to melt one pound of iron, the specific heat is multiplied by the number of degrees through which the temperature is raised.

It has been found that the specific heat of iron becomes greater as the temperature rises, and that between 2260 and 2850 degrees Fahr. the average value is 0.23 B.t.u. per pound. Therefore in superheating to 2850 degrees heat additional to that required for the mere melting in the amount of the number of degrees above 2260 degrees multiplied by 0.23 B.t.u. is required.

The quantity of heat necessary to change the iron from the solid state to the liquid state at the melting point without change of temperature is called the *latent heat of fusion*. This is 41.3 B.t.u. per pound, and this quantity of heat must be added to the other items.

The equation for the calculation of the total quantity of heat necessary for melting and superheating to a definite temperature one pound of iron is as follows:

$$Q = 0.19 \times (T_m - T_a) + 0.23 \times (T_p - T_m) + 41.5$$

where Q = B.t.u. necessary to melt and superheat one pound iron.

T_m = Melting temperature (average for gray iron 2260 degrees Fahrenheit).

T_a = Average temperature of blast air (60 degrees Fahr.).

T_p = Temperature of iron at spout.

For example—iron to be melted and superheated to 2650 degrees Fahrenheit.

Heat for melting $0.19 \times (2260 - 60) = 0.19 \times 2200 = 418$

Superheating $0.23 \times (2650 - 2260) = 0.23 \times 390 = 90$

Heat of fusion 41.5

Total B.t.u. for one pound of iron 549.5

For a 35,000 pound heat the total requirement is

$$35,000 \times 549.5 = 19,200,000 \text{ B.t.u.}$$

Carbon burned completely to carbon dioxide evolves 14,550 B.t.u. per pound. Consequently to supply 19,200,000 B.t.u., 1,320 pounds of carbon are required. This, of course, represents 100 per cent efficiency, which is not obtained in any heating operation. Assuming an efficiency of 30 per cent, the coke requirement in this case is 4,900 pounds and the melting ratio is

$$\frac{35,000}{4,900} = 7.15$$

This figure will be recognized as being within the range of the usual experience.

For the purpose in hand at present it is necessary to calculate the thermal efficiency of the cupola operation, neglecting, as stated before, such items as the heat necessary to heat up the lining, melt the slag, and that which passes out of the cupola in the stack gases in the form of sensible and latent heat. In order to do this, knowing the heat required to melt one pound of iron,

and the size of the charge on the one hand and the total coke used on the other, the total heat necessary for melting and superheating is calculated and divided by the total B.t.u. supplied by the combustion of the coke, assuming the latter to be complete. The thermal efficiency is actually somewhat lower than the calculation indicates because the combustion is seldom complete. However for the purpose of this discussion a basis of comparison is being sought and this figure will suffice. It is readily seen that if the efficiency under faulty combustion condition is reasonable, any improvement in combustion is all the more to be sought.

An example of this calculation may now be taken from Table 2.

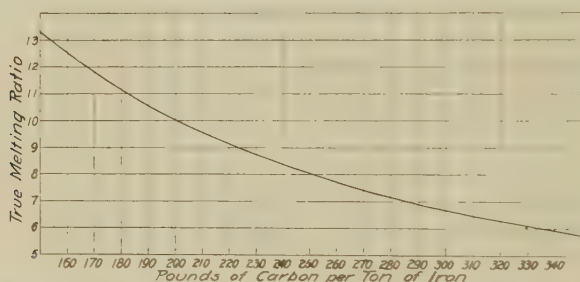


FIG. 1—TRUE MELTING RATIO FOR POUNDS OF CARBON PER TON OF IRON

Total heat required to melt and superheat 68,000 pounds iron to 2700 degrees Fahr.

$$68,000 \times 560.7 = 38,464,020 \text{ B.t.u.}$$

Total heat supplied by complete combustion of 8,220 pounds 90 per cent coke

$$8220 \times 0.90 = 7,390 \text{ pounds carbon}$$

$$7390 \times 14,550 = 107,200,000 \text{ B.t.u.}$$

$$38,464,020$$

$$\text{Thermal Efficiency} = \frac{38,464,020}{107,200,000} = 35.9 \text{ per cent}$$

This calculation can easily be made from only two factors (1) the weight of coke consumed per ton of metal produced, and (2) the temperature of the metal at the spout. The carbon content of the coke must also be known and the weight of coke reduced to weight of carbon.

In the chart of Fig. 1 the true melting ratio (pounds of iron melted by one pound of carbon) is determined graphically from the number of pounds of carbon consumed in melting one ton of iron. Having found the true melting ratio, and knowing the temperature, the thermal efficiency can be determined from the chart of Fig. 2. For instance, if the true melting ratio is 10:1 (ordinate) and the temperature 2750 degrees Fahr., the abscissa shows the thermal efficiency to be 39.4 per cent.

The chart of Fig. 3 represents graphically the quantity of heat in B.t.u. necessary to melt one pound of iron and to superheat to the temperature shown on the abscissa. Thus, if the temperature is 2750 degrees Fahr., the heat necessary to melt and superheat the iron is 572 B.t.u. This applies only to ordinary gray cast iron of the average analysis as previously explained.

Returning to Tables 1 and 2, the thermal efficiencies calculated by the methods just outlined are shown in the case of straight-lined cupolas of 54-inch inside diameter to vary from 26.7 per cent to 37.2 per cent and the average 31.3 per cent. In the case of the boshed cupolas the variation is from 25.4 to 35.9 per cent, averaging 31.7 per cent. The indication here again is that boshing of the lining has no appreciable effect on the thermal performance of the cupola.

More important than this, however, is the variability of the performance of different cupolas of the same size. This is shown in Table 3.

Table 3

Straight-lined			Boshed		
Kind of Work	Thermal Efficiency, Per Cent	Total Coke Ratio	Kind of Work	Thermal Efficiency, Per Cent	Total Coke Ratio
Seating	37.2	8.6	Light	35.9	8.3
Light cstgs.	36.9	8.1	Shock abs.	34.8	8.1
Sanitary	35.9	7.1	Tractor	33.0	7.7
Mch. tools	29.4	7.1	Pumps	30.2	6.8
General	27.8	7.1	Soil pipe	29.9	6.6
Heating boilers ..	27.0	6.3	Cylinders	29.6	6.7
Pipe fittings	26.7	6.3	Automobile	25.4	6.6

Unfortunately insufficient data are available to make possible a valid conclusion but certain indications are shown. There seems to be no marked connection between the type of castings made and the thermal efficiency. The coke ratio (pounds of iron melted by one pound of coke) has apparently only a slight relationship to the actual thermal efficiency, and hence the latter

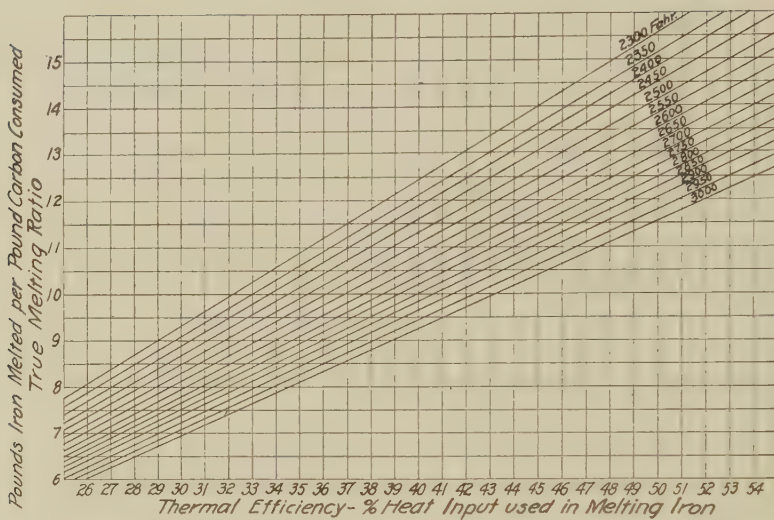


FIG. 2—CHART FOR DETERMINING THERMAL EFFICIENCY

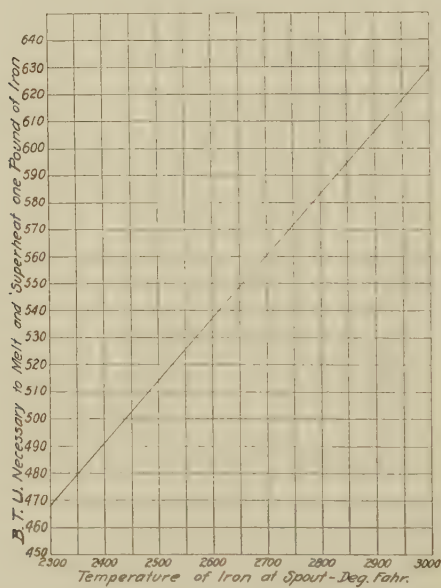


FIG. 3—B. T. U. NECESSARY TO MELT ONE POUND OF IRON AND TO SUPERHEAT TO DESIRED TEMPERATURE

which has been corrected for several variables as previously explained offers a better basis of comparison.

Air Supply

So much for the side of the story relating to coke consumption. The air supply should now be considered in detail. It is to be noted in Tables 1 and 2 that no standard pressure or volume of air is being used. In two cases no data concerning the air relations were given at all indicating that a very important means of control is being overlooked in those plants. It is interesting to note that the average blast pressure is 13.5 ounces for straight-lined cupolas and 11.4 ounces for the boshed type. This is the condition which naturally would be expected to exist since probably the principal function of the bosh is to facilitate the penetration of air through the coke bed. The pressure in itself has nothing to do with the actual combustion except to insure the presence of air in the proper place and to maintain the correct rate of combustion. Obviously, with high pressure an excess of air may be introduced and this will lead to a heavy coke consumption and to oxidation of the iron.

By far the most important factor is the blast volume. When carbon burns to carbon dioxide, that is when combustion is complete, a very definite weight of oxygen is consumed by each unit weight of carbon. For the combustion of each pound of carbon 2.667 pounds of oxygen are required and 14,550 B.t.u. are made available. This, as explained previously, results in the highest possible evolution of heat and is the goal which should be striven for. Three other reactions are possible but a discussion of them does not properly belong in this paper.

Under average atmospheric conditions 153 cubic feet of air is required to supply the oxygen necessary for the complete combustion of one pound of carbon, and this will figure out to 27,540 cubic feet per ton of iron melted at a ten to one ratio, or approximately 30,000 cubic feet per ton on an eight to one basis.

It will be seen from Tables 1 and 2 that no standard is apparent in the operation of the sixteen cupolas under consideration. A considerable variation in blast volume is shown but this figure does not offer a suitable basis of comparison because

it has no reference to the amount of coke burned or the iron melted. It is therefore necessary to determine the volume of air supplied per ton of iron melted, and even more specifically, the volume of air supplied per pound of carbon. Considered from these points of view wide variation exists. While it is apparent that an average of the quantities of air supplied is not valid, there is an indication that for the most part, the boshed cupolas are operated with more air than those that are straight-lined.

Among the straight-lined cupolas three are operated with slightly less than theoretical air for the carbon consumed, three with a decided deficiency, and one with a considerable excess of air. Three of the boshed cupolas are operated with about the same excess of air as the latter, two with slightly less than the theoretical and one with a deficiency even greater than the lowest of the straight-lined cupolas. Strange as it may seem, the boshed cupola to which the volume of air most nearly theoretical was supplied shows the lowest thermal efficiency and that one into which the lowest volume of air was introduced shows an efficiency above the average. The most efficient of the straight-lined cupolas shows an air supply considerably less than the theoretical and the least efficient shows a still smaller amount. These conditions simply point to lack of balance in the combustion. The supply of a deficiency of air to a high coke bed for instance, will result in the production of carbon monoxide by the reduction of the carbon dioxide first formed by the overlying incandescent coke according to a reaction which absorbs heat, and which therefore causes a loss of efficiency. The way in which the coke is placed in the cupola and the distribution of the air are therefore important factors to be considered.

Theoretical Calculation of Coke and Air

The average melting point of gray iron is 2260 degrees Fahr., but for a very accurate operation the actual melting point of the particular iron in question should be determined. Usually the molten iron leaves the spout at 2700 degrees Fahr. In order to determine the heat necessary to melt and superheat a given charge of iron, the chart of Fig. 3 is referred to. In this case it will be found that the total heat necessary is 560 B.t.u. per

pound. If the charge is to be 20,000 pounds per hour the total requirement per hour will be

$$560 \times 20,000 = 11,200,000 \text{ B.t.u.}$$

It is then necessary to determine the weight of coke required to supply this amount of heat. Assuming the carbon content of the coke to be 90 per cent, one pound of coke, burned completely to carbon dioxide, will produce

$$0.90 \times 1.0 \times 14,550 = 13,100 \text{ B.t.u.}$$

The weight of coke required to produce 11,200,000 B.t.u. will be

$$11,200,000 \div 13,100 = 855 \text{ pounds}$$

At 100 per cent efficiency, 855 pounds of coke should melt 20,000 pounds of iron, or the melting ratio will be

$$20,000 \div 855 = 23.4$$

This, of course, is an impossible achievement. It has been found that an efficiency of 35 per cent can be attained without difficulty. The weight of coke necessary to attain that efficiency will be

$$855 \div 0.35 = 2420 \text{ pounds per hour}$$

and the melting ratio will be

$$20,000 \div 2420 = 8.26$$

Of course under better melting conditions an efficiency of as high as 60 per cent has been attained and in that case the coke requirement will be

$$855 \div 0.60 = 1422 \text{ pounds per hour}$$

and the melting ratio will be

$$20,000 \div 1422 = 14.02$$

Suppose it is desired to arrange the operating conditions of the cupola so that the over-all melting efficiency will be 35 per cent in melting 10 tons of iron per hour for eight hours. The hourly coke requirement will be 2420 pounds including the bed. A bed charge for a 54-inch cupola extending to 30 inches above the tuyeres will be approximately 1,325 pounds, providing the coke weighs 25 pounds per cubic foot. Theoretically the bed coke should not enter into the calculation because it acts principally as a refractory support to hold the charges in the melting zone, and the actual fuel should be supplied by the intermediate charges. Actually some bed coke is always consumed and in a number of known cases the coke in the drop amounts to 1,000 pounds. Obviously the longer the heat the less is the influence of the bed

coke consumption on the over-all melting ratio. In this hypothetical case it will be assumed that the drop is 1,000 pounds and 325 pounds will therefore be consumed as fuel. For an eight-hour heat this will amount approximately to 40 pounds per hour.

In a 54-inch cupola the iron charges are usually 2,000 pounds, and since the melting rate is 10 tons per hour there will be ten charges per hour and eighty for the entire heat. If 40 pounds of coke per hour is assumed to be the bed coke consumption per charge, this will amount to only 4 pounds, and it is doubtful whether many cupolas are operated that closely. However, the intermediate coke must be taken as 2420 — 40 pounds or 2,380 pounds for ten charges, and therefore 238 pounds for each charge. The intermediate melting ratio will then be

$$2000 \div 238 = 8.4$$

which should not be difficult to attain.

When the coke charges have been worked out, it is necessary to calculate the volume of air necessary to burn it completely. It has already been stated that 153 cubic feet of air are necessary to burn one pound of carbon to carbon dioxide. If the coke contains 90 per cent carbon, the weight of carbon will be

$$238 \times 0.90 = 214 \text{ pounds}$$

and the air necessary

$$214 \times 153 = 32,742 \text{ cubic feet}$$

Since ten charges per hour are used, each charge will require six minutes and the supply of air should be

$$32,742 \div 6 = 5457 \text{ cubic feet per minute}$$

Allowance for slippage and leakage will bring this to approximately 6,000 cubic feet per minute which corresponds to the volume of air recommended for this size cupola by the manufacturers.

The cupola may be operated on the basis of these calculations with the assurance that the major conditions have been taken into consideration. It is not expected that exact results will be obtained at the first attempt because of the large number of variables present which are difficult to control. Careful attention to the details of operating the individual cupola should result in good heats within a very short time, however. When this set of conditions has been found to give satisfactory results,

the operator should try for a better melting efficiency by making another set of calculations based, let us say, on 40 per cent, and regulate the coke and air accordingly. Higher efficiencies can be obtained by just such careful attention to the details of operation, and with them comes economy in a number of ways. The coke consumption is decreased primarily, and this leads to better iron since the carbon and sulphur contents are also decreased. The melting rate should also be increased.

The question may now be raised as to the value of a boshed lining. The results shown in Tables 1 and 2 indicate no especial advantage, but it seems evident that other things being equal, the weight of bed coke should be decreased because the capacity of the bosh is less than would be the case were the cupola straight-lined. The size of the coke enters into this consideration also since large coke will fill the space required with a lower weight, and small coke will increase it materially. The coke should not be too large because the surface exposed to the blast air is relatively small, and much of the oxygen may not react and thus be free to oxidize the iron. If it is small, the pressure is increased and the tendency toward slagging and bunging up is increased. The average size which works satisfactorily is 4 to 6 inches. The reactivity of the coke must also be considered, but this is a matter so complex that it cannot be covered in this paper. The bosh has an additional advantage in that it prevents coke and slag from entering the tuyeres, and this in the opinion of some foundrymen is the only reason for using it. From a combustion standpoint, it has a value due to its shape which permits better blast penetration, and tends to keep the air from passing up the walls of the cupola without entering into reaction with the coke.

The Value of a Second Row of Tuyeres

Table 1 shows the operating results of only one cupola equipped with two rows of tuyeres, and the efficiency in this case is lower than the average. Table 2 records the results of three cupolas so equipped, one of which was the most efficient of the series, one the least efficient, and the third was below the average. Since only 25 per cent of the cupolas included in this comparison are operated with upper tuyeres, it seems that no defi-

nite conclusion can be drawn. It appears, however, that other variables are of greater importance, and the consideration of the value of upper tuyeres may well be left until a greater mass of information is available for comparison.

Conclusion

Based on a comparison of actual results of practical operation of two series of 54-inch cupolas, a rational procedure for cupola operation has been set forth. It is realized that this does not cover every detail and no attempt has been made to discount the value of practical experience. It is hoped, however, that cupola operators will note the highly variable procedures which are in use and that they will try to adapt the methods outlined to their own practice with the idea of making it conform with the best practice of which records are available.

Quality of Pig Iron and Castings as Affected by Blast Furnace Practice

BY A. L. BOEGEHOLD,* DETROIT, MICH.

There is probably no raw material used in the foundry which has received more blame for defective castings, than pig iron. It has always been a peculiarity of human nature to be suspicious of the unknown and that is why pig iron is regarded as a bad character. There have no doubt been many occasions when pig iron has been held responsible for some casting defect simply because of lack of adequate evidence to establish its innocence. Pig iron has probably also many times by virtue of rather flimsy evidence been pronounced guilty of causing defects.

What percentage of the defects attributed to pig iron are warranted is hard to determine. Also how many defects are there for which pig iron is the cause without ever being suspected? There are a number of defects common to gray iron castings which might be caused either by the use of the wrong pig iron or by a divergence from proper procedure in melting, charging, molding, etc. For example, here are a few of such defects:

Hard Edges
Hard Iron
Porosity

Cracked Castings
Soft Castings
Low Combined Carbon

*Metallurgist, General Motors Research Laboratories.
Discussion of this paper begins on page 683.

An epidemic of any of these or similar defects is the signal for a careful checking up on analysis of melting stock, proportions of charge, details of cupola operation, casting temperature, and other foundry details.

If the cause is not discovered in the foundry practice, the manager will as a last resort, change the pig iron in the charge. If the pig iron is the cause, this procedure may stop the trouble, but then again it may not, if the substituted pig iron possesses the same defect in its make-up. The trouble is we have no criterion for the selection of pig iron—no yardstick with which to determine whether a pig iron will or will not cause certain defects in our castings.

There has been a great deal of discussion in the past three years at meetings of the A. F. A. and A. I. M. E. on the quality of pig iron and on the effect of that quality upon the quality of castings made therefrom. In the course of this discussion there has been praise for the pig iron made years ago and also denunciation of the same. Blast furnace men have pointed to the improvement in blast furnace operation which has taken place in the past twenty years, so that now there is a much smaller possibility of producing bad pig iron than there was when blast furnace operation was in a much cruder state. At the conclusion of all this discussion I know there were many foundrymen who were more at sea than ever on the question of good and bad pig iron. Not a few were ready to believe that the trouble was not in the pig iron but in its use.

The foundry managers of General Motors Corporation Divisions were just as deeply interested in this question as others in the profession, so they asked that an investigation be conducted to clear up some of the mystery about pig iron. Steps were therefore taken to set up a small foundry operation but large enough to simulate conditions occurring in production foundries so that pig irons from various blast furnaces could be melted as part of the cupola charge going to make gray iron for automotive castings. Fig. 1 shows the foundry in operation. Gray irons made from these various pig irons were subjected to a variety of tests to determine the relation between the properties of the

cast iron and the conditions of operation during the manufacture of the pig iron.

Method of Investigation

In brief, the method of investigation consisted of making a series of physical tests upon cast irons of the same analysis poured at the same temperature and made under similar conditions from pig irons of the same chemical specifications obtained at different times from different blast furnaces and whose blast furnace history was known as completely as possible. The variation in properties of the cast irons obtained was taken as an indication of differences in quality of the pig iron used. The following details pertain to the method of procedure:

1. Eleven casts of about 75 tons each of No. 2X malleable pig iron, containing silicon as near 2.50 per cent as possible, were obtained from seven different blast furnaces over a period of a



FIG. 1—EXPERIMENTAL FOUNDRY

year. During the manufacture of these samples a record was made of all blast furnace operating conditions which could be obtained. A typical data sheet is shown on page 95.

2. Tests made on each of these pig irons were

1. Chemical Analysis.
2. Microstructure.
3. Fracture.
4. Dilation Characteristics.
5. Spectrum Analysis.

3. These pig irons were used as raw material for the production of cast iron flywheels. The analysis aimed at for these castings was

Carbon	3.00-3.30
Silicon	2.25-2.35
Mn.	.55- .75
S.	.10 max.
P.	.20 max.

Pig iron being the subject investigated, it was necessary to maintain all cupola conditions with as little variation as possible. The standard melting conditions which we tried to maintain at all times were:

- (a) Charge—1000 lbs. made up of
- 500 lbs. of pig iron of the particular cast being tested.
 - 137 lbs. of steel (low carbon punch press scrap).
 - 250 lbs. of gates and sprues from the cupola heat of the day before.
 - 113 lbs. of 7 per cent silicon silvery iron.
 - 125 lbs. of coke.

Sample Data Sheet

PIG IRON—BLAST FURNACE DATA

G.M. Purchase Order No.....	G.M. Research Lot No.....
1. Furnace No.	Location
2. Superintendent	Date Produced
3. Heat No.	Type Charging Top
4. Ore Charge.....lbs.	Coke Charge.....lbs.
Ratio.....	
5. Composition of Burden.	

	Pounds	Per Cent
Kind of Ore.....	.....	.....
.....		
.....		
.....		
.....		

6. Kind of Coke	Analysis
1. Shatter Test	Fixed Carbon
2. True sp. gr.	Vol. Hydro C.
3. App. sp. gr.	Ash
Porosity	Sulphur
	Water

7. Dry-Wet Blast?
8. Blast Temp.....max. min. cycle.
9. Blast Pressure.....lbs. sq. in. lbs. sq. in. max. lbs. sq. in. min.
10. Air per hour.....cu. ft. lbs.
11. Fuel burnt per hr. lbs. lbs. per sq. ft. area, at max. dia.
12. Pounds of air per lb. of fuel..... Air per lb. of carbon.....lbs.
13. Blast velocity through tuyeres.....ft. per min.
14. Composition of Top Gases....% CO% CO ₂% H% N
15. Temperature of Top Gases.....
16. Burden per hr.....lbs. lbs. per sq. ft. area at max. dia.
17. Composition of slag.

Flushing Slag	Casting Slag	
SiO ₂ .....	.....	
Al ₂ O ₃ .....	.....	Appearance of Slag...
CaO .....	.....	
MnO .....	.....	
FeO .....	.....	Slag per ton of iron produced.....lbs.
MgO .....	.....	
CaS .....	.....	

18. Weight iron produced per hour.....lbs.
Weight per sq. ft. area at max. dia. per hour.....lbs.
19. Depth of metal in hearth at tapping.....ft.
20. Casting Temp.....°F.
Average.....°F.
21. Time between cast.....hours.
22. Dimensions of Furnace.
1. Stock line to tuyeres.....ft., ...in.
2. Tuyere level to hearth.....ft., ...in.
3. Size and number of tuyeres.....
4. Iron notch to cinder notch.....ft., ...in.
5. Dia. at top of bosh.....ft., ...in.; straight.....ft., ...in.
6. Dia. at hearth.....ft., ...in.
7. Cubical contents of furnace.....cu. ft.

23. Chemical Analysis:					
Average of Five Pigs					
T.C.	C.C.	Mn.	P.	S.	Si.
.....					
.....					
.....					
.....					

24. Atmosphere Temperature.....°F.
25. Barometric Pressure.....inches Hg.
26. Humidity.....%. gr. per cu. ft.

Test specimens were not cast until more than three days after changing to the use of a new cast of pig iron in order to get the effect of the back scrap containing the new pig iron.

- (b) Coke—Burning rate to be less than 3.5 minutes for 250°F. temp. rise and minimum temp. rise of 270°F.
(See appendix for coke test.)

- (c) Blast—1300 cu. ft. per min.
Atmospheric temperature, pressure and humidity readings were made during every heat.

Coke bed 36 inches above tuyeres.

4. The cast iron produced in this manner was poured into a variety of physical test samples designed to permit the measurement of

- (a) Tensile strength of 1¼" dia. bar as cast.
- (b) Tensile strength of ⅝" dia. bar as cast.
- (c) Transverse strength of 1¼" round by 12" bar.
- (d) Hardness of various sizes of section cast in green sand and in core sand.
- (e) Machinability of ⅜, ¾ and 1¼" slabs.
- (f) Fluidity.
- (g) Volume shrinkage.
- (i) Linear shrinkage.
- (j) Density.
- (k) Microstructure.

Variables Considered

In conducting an investigation of pig iron, the ideal course naturally is to maintain all variables constant. Practically that is quite impossible to accomplish, due to inability to regulate some of the factors, including.

1. Amount of water in the atmosphere.
2. Temperature of the atmosphere.
3. Pressure of the atmosphere.
4. Variation of several properties of pig iron due to variable blast furnace conditions.

The best we can do is to record these items and take them into consideration in our conclusions. Another variable affecting the results of our physical tests on the cast iron is the variation in silicon content. In spite of precautions taken to distribute the charge properly and to always leave about three hundred pounds of metal in the well of the cupola, there was a variation in silicon content from heat to heat. This of course is a difficulty common to all foundries, unless special equipment, such as mixers or large forehearth are installed to remedy this condition. This variation in silicon was made use of, however, in studying effect of silicon upon hardness and was taken into consideration in forming other conclusions.

Information Used to Calculate Performance Values

After collecting the data at the blast furnace during the production of each of our sample casts of pig iron, the information was used to calculate performance values. The results of these calculations are tabulated on a summary sheet shown as Table 1. Study of this sheet will bring home to you the great variation in the methods existing at various furnaces in the production of the same kind of pig iron.

The conversion of iron ore to iron is a chemical process and the nature of the resulting product is determined by the kind of chemical reactions occurring in the blast furnace and how far towards equilibrium those reactions progress. At the high temperatures existing inside the furnace, reactions proceed at great rapidity, therefore, small differences in time of contact of the chemical compounds, as well as variations in chemical and physical environment in which the major reactions of ore and silica reduction will produce considerable difference in the character of the end product.

Blast Furnace Conditions Vary

We have always known in a general way that there is considerable variation in conditions related to blast furnace operation but have most users of pig iron ever really appreciated just how much these conditions do fluctuate? Possibly if this point is more thoroughly realized it will begin to be apparent that pig irons

Table 1
BLAST FURNACE OPERATING DATA

Heat No. and Furnace	1A	2A	3A	4A	5B	6C	7D	8E	9E	10F	11G
Lbs. coke per long ton iron produced	2160	2130	1930	2000	2120	1845	1860	2440	1765	2170	2000
Lbs. iron produced per hr. per sq. ft. area	121.3	99.8	122.0	115.0	113.5	135.3	179.0	95.8	117.0	123.0	96.2
Lbs. burden descending per hr. per sq. ft. area	228.0	178.5	221.2	234.5	229.8	270.0	363.5	212.0	214.5	243.0	179.2
Lbs. coke burnt per hr. per sq. ft. area	117.1	94.9	105.1	102.5	107.5	111.0	148.2	104.2	92.7	119.4	84.5
Lbs. air per lb. carbon in coke	4.53	5.25	4.55	4.98	5.37	4.27	4.48	5.68	6.30	5.52	6.03
Lbs. air per lb. of burden	2.11	2.54	1.96	2.00	2.30	1.64	1.67	2.46	2.41	2.46	2.41
Lbs. air per hr. per sq. ft. area at max. dia.	482	432	437	468	526	443	606	522	516	574	432
Lbs. air per lb. of iron produced	3.98	4.53	3.58	4.07	4.66	3.29	3.39	5.45	4.42	4.66	4.60
Grains water per cu. ft. of air	3.2	6.1	2.6	2.2	2.7	1.56	2.3	1.51	2.8	1.75	1.3
Lbs. water in blast per ton iron produced	55.0	121.6	38.5	35.5	53.2	22.0	32.0	34.0	51.8	33.0	23.8
Blast temperature	1185±175	1300±100	1275±125	1130±130	1170±80	1050±50	1050±50	1110±150	1100±150	1075±265	1100±150
Blast pressure, lb. per sq. in.	9.5-12.0	11.0-13.0	10.5-11.0	9.0	13.5-19.5	14.0-18.0	12.0-14.0	11.5	11.0	13.5	13.5
Per cent ore in burden	85.60	91.40	89.90	81.5	100.0	85.79	90.31	90.0	90.0	91.7	88.9
Per cent sintered flue dust in burden	8.38	3.45	10.10	10.8	0.0	8.17	2.14	10.0	10.0	8.3	11.1
Per cent foreign scrap in burden	6.02	5.15	0.0	7.7	0.0	6.04	7.55	0.0	0.0	0.0	0.0
Per cent SiO ₂ in slag	38.56	37.54	35.21	42.60	40.44	40.20	38.80	33.40	35.6	35.8	39.93
Per cent Al ₂ O ₃ in slag	11.40	14.45	13.34	10.34	10.10	14.05	11.84	16.00	16.20	15.30	13.31
Per cent CaO and MgO in slag	45.88	42.62	47.24	.....	45.98	42.38	47.04	48.07	45.67	47.62	37.77
Appearance in slag	Acid	Acid	Basic	Acid	Acid	Acid	Acid	Basic	Acid	Basic	Acid
Lbs. of slag per ton of iron	1215	1100	1108	1272	1282	1345	1070	1222	1044	1170	1205
Casting temperature of iron	.....	2617-2670	2650-2790	.....	2635-2660	2633-2710	2650-2750	2705	2783	2668	2707

which seem to be the same when viewed from the standpoint of chemical analysis, must be subject to considerable variation in physical character due to the constant fluctuation of the blast furnace operating conditions. If means for reducing the amount of these fluctuations are available, it behooves the blast furnace operator to make use of them that he may have better control of the quality of his product.

In the first place we know that coke varies tremendously. Coke in itself is responsible for some of the worst variations that occur in blast furnace operation, as we shall see by examining data tabulated as Table 1. In this table information is given on blast furnace conditions existing during the manufacture of the eleven casts of pig iron obtained from seven different blast furnaces. The heats of iron are identified by numbers from one to eleven and the blast furnaces in which the iron was made are distinguished by letters from A to G.

Starting at the first item, the pounds coke used per ton of iron produced, one of the things which all blast furnace operators keep close check on, shows great variation from 1,765 to 2,440 and it happens that this variation was in one furnace in one week's time. If it was necessary to use 2,440 pounds of coke to get enough heat to produce 2.50 per cent silicon iron, then there must have been tremendous difference in the coke used or in some other factor when with 1,765 pounds of coke per ton of iron enough heat was supplied to obtain 2.33 per cent silicon. Some of this discrepancy is probably due to the difference in slag composition being basic in one case and acid in the other. (See information of Table 1 on appearance of slag.)

To compare the operation of the different blast furnaces on a uniform basis, the quantities of air, ore, coke, etc., flowing through the furnace are reduced to quantities per one square foot of furnace cross-sectional area at the maximum diameter which is at the top of the bosh. This basis makes the data directly comparable and shows rate of material flow per unit, giving us a very different picture from that obtained by comparing total furnace data. The great difference in operation of furnaces studied is astonishing.

The third item gives the pounds of burden descending per hour in each vertical column of one square foot cross-sectional area. This speed of travel varies from 178.5 lbs. during production of lot 2 to 363.5 lbs. during production of lot 7. The latter rate was attained in a furnace only 68 feet from hearth to stock line, while the former was in a 72 foot furnace. When we take into consideration the height of the furnace in determining the relative time that any particle of ore remains in the furnace, we find that each particle of burden remained in A furnace while making heat 2, 2.16 times as long as the burden remained in D furnace while making heat 7. If the proper amount of time to reduce iron ore was used in G furnace, then certainly insufficient time has been allowed for complete reduction of the ore while making heat 7 in D furnace. The time of the ore in the furnace in making the other nine heats, falls between these two cases cited.

The rate of travel of this burden of course depends on the rate of coke combustion. If a readily combustible coke is used, the rate of coke combustion is determined by the rate at which air is supplied. Increasing the speed of combustion by faster delivery of air is possible only up to the maximum burning rate of the coke. This maximum burning rate varies widely among different cokes, and even among cokes which are accepted as being alike on the basis of analysis and per cent cell space. The performance of the various furnaces indicates that due to the very combustible quality of the coke in some instances, blowing in large quantities of air speeds up combustion and burden travel, while in other cases increasing the air does not speed up combustion simply because the coke is not a fast burning coke and will not respond to the increase in blast volume. The differences in combustibility of cokes is well illustrated by curves of Fig. 2 obtained by testing these cokes by means of the test described in the appendix to this paper.

In the graph of Fig. 2 are shown the combustibility characteristics of six cokes, four of which are cokes used in the blast

furnaces while making the casts of pig iron obtained for this investigation. It is perfectly obvious that a coke possessing the characteristics shown in curve 6 where it takes 8.0 minutes to liberate enough heat to raise the temperature 250 degrees Fahrenheit when burned with oxygen, cannot be made to burn in a blast furnace as fast as a coke having the character shown by curve 4 where a 250 degree Fahrenheit temperature rise is obtained in 2.0 minutes.

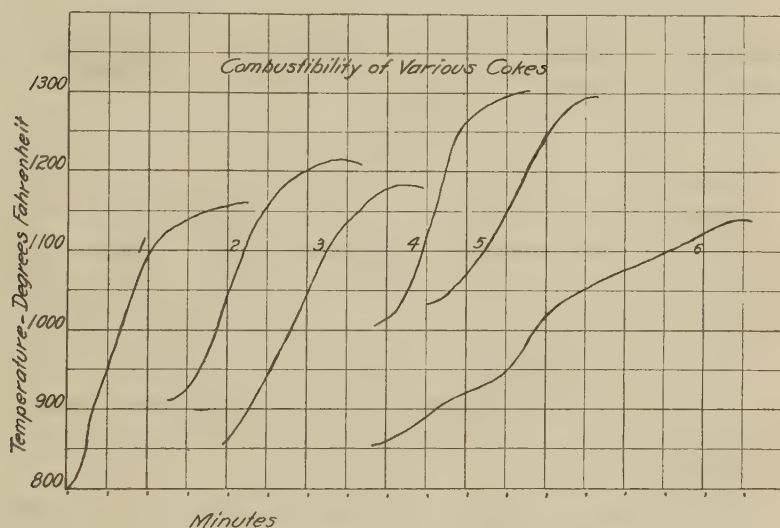


FIG. 2—COMBUSTIBILITY OF VARIOUS COKE

Curve No.	Description	Total Temp. Rise in Degrees Fahr.	Time for 250 Degrees Fahr. Temp. Rise in Minutes
1	Petroleum Coke	360	1.6
2	A good beehive coke	300	2.2
3	Coke for pig iron No. 7...	325	2.65
4	Coke for pig iron No. 6...	295	2.0
5	Coke for pig iron No. 2...	260	3.5
6	Coke for pig iron No. 11..	285	8.0

Table 2 shows how the rate of iron production varies with the quality of the coke. The combustibility results represent averages of six test runs on each coke.

Table 2

Pig Lot No.	Combustibility of Coke			Pounds of Iron Produced per hr. per sq. ft. area of furnace
	Ignition Temp.	Total Temp. Rise	Time in Minutes for 250 °F. Temp. Rise	
11	860-930	269	7.0	96.2
2	930-1080	266	3.2	99.8
6	990-1070	278	2.3	135.0
7	860-915	318	2.2	179.0

It is quite apparent that a fast burning coke is a requisite for rapid production of pig iron.

Foundrymen are using pig iron made to the same chemical specifications, but under widely differing blast furnace conditions, due to the use of cokes as different as these illustrated. It is quite probable that the properties of the resultant cast iron reflects these variations in some way.

In the case of heat 6, furnace C and heat 7, furnace D, the air used per pound of coke carbon was about the same, viz., 4.27 and 4.48 pounds air per pound carbon in coke, but the coke burnt per hour in furnace C was 111 pounds as against 148.2 pounds in furnace D. This was due simply to the fact that air was supplied faster to furnace D. Because the coke was capable of rapid combustion the heat was produced and utilized at a faster rate.

In furnace D there were supplied 606 pounds of air per hour per square foot of area, while in furnace C only 443 pounds were supplied per hour per square foot area. The reason for the use of about equal amounts of air per pound of carbon is found in the similarity of combustibility character of the two cokes as shown by combustibility curves of these two cokes given in curves 3 and 4, Fig 2. Although the ignition temperature of coke 4 is 150 degrees Fahr. higher than that of coke 3, the burning rate is similar.

By blowing air faster into furnace C the rate of burden travel could probably have been increased to equal that in furnace D. On the other hand, in the case of heat 9 from furnace E we have air supplied at a faster rate than in the case of heat 6, furnace C. There were 516 pounds per hour per square foot cross-section as against 443, but the quality of coke used for heat 10 was such that the air could not be used as fast as it was supplied. Only 92.7 pounds coke per hour per square foot were burned as against 111.0 in furnace C in spite of greater air being supplied to furnace E. This results in excessive air being supplied per pound of coke burnt in furnace E. There were 6.3 pounds of air per pound of carbon as against 4.27 in furnace C.

The slow rate of coke combustion is, of course, responsible for the slower burden travel and also for the larger amount of air supplied per pound of iron produced. In heat 8 made in E

furnace, for every pound of iron produced, there were 5.45 pounds of air used, while in heat 6 made in C furnace, only 3.29 pounds of air were used per pound of iron produced. This air combines with carbon in a small region right in front of the tuyeres.

According to Kinney¹ there is a sort of laterally flattened sphere some 30 to 36 inches in diameter, measured on the tuyere axis in front of each tuyere where there is free oxygen and excessive CO₂ so that oxidation of the iron can take place. In the case where air is blown in at a high rate and the coke being used is slow to unite with the oxygen, this sphere will be larger in extent and contain more free oxygen.

Royster's and Joseph's² conclusion that the stock in a blast furnace travels in converging lines to the areas in front of the tuyeres where combustion takes place indicates that practically all of the iron must pass through these zones and come in contact with the gases which are capable of reoxidizing the iron. The proportions of O₂, CO₂ and CO in these zones depends on the rate of supplying air and the combustibility of the coke. In an operation like that when heat 8 was produced in furnace E, where the coke was slow burning and excessive air was supplied, the gases in front of the tuyeres would be much more oxidizing in nature than in the case of the operation of C furnace when heat 6 was produced where a very combustible coke was used and a minimum of air per pound of iron was supplied. The oxidation at this point, however, would probably not be an oxidation of the iron as much as burning out of carbon and silicon. This is presumably the reason why the silicon content of an iron is sometimes lower than is indicated by its temperature as it leaves the furnace.

An iron containing silicon normal to its temperature before passing through the combustion zone may come out of the tap

¹*Study of the Reactions in an Iron Blast Furnace*—S. P. Kinney, P. H. Royster and T. L. Joseph. U. S. Bureau of Mines Bulletin.

²*Study Stock Flow in Furnaces*—P. H. Royster and T. L. Joseph. Iron Trade Review, March 13, 1924.

hole with lower silicon than normal for its temperature because of:

1. Burning out of silicon in passing through the combustion zone, and
2. Increase of temperature due to heat liberated by oxidation of the silicon.

Let us assume that we could measure the temperature and silicon content of iron inside the blast furnace and we were studying these conditions at different times during the day on one blast furnace. We might find in one case an iron at 2650 degrees Fahr. just before it passed through this combustion zone, to contain 2.50 per cent silicon, which then passed through the combustion zone without becoming oxidized. Another determination later in the day might show us an iron with the same kind of a slag at 2725 degrees Fahr. and containing 2.75 per cent silicon. Now, if the second iron passes through a more oxidizing combustion zone than the first, causing a 0.25 per cent loss of silicon by oxidation resulting in maybe a 25 degree increase in temperature, we will have coming out of the tap hole an iron of 2.50 per cent silicon content but 100 degrees Fahr. hotter than the other 2.50 per cent silicon iron at 2650 degrees Fahr. This temperature difference of like silicon content irons would be still greater if the latter iron were made with a basic slag and the former with an acid slag. Control of coke quality would control such a situation by reducing the amount of oxidation possible in front of the tuyeres.

Table 1 shows also the variations in blast temperature, pressure, composition of burden, slag analysis, slag volume, casting temperature and amount of water introduced as humidity per pound of iron produced. The variation in the last mentioned item amounts to 550 per cent. This factor is very important in its influence upon coke consumption and the production of sufficient heat in the furnace. Of the eleven heats recorded here, the largest amount of water introduced per ton of iron produced was 121.6 pounds, but under some conditions it could easily amount to 200 pounds of water per ton of iron. For example, under the conditions of operation of heat 8 in furnace E, where there were 5.45 pounds of air supplied per pound of iron produced,

if the humidity had been 80 per cent at 80 degrees Fahr. or 9 grains per cubic foot of air, there would have been 213 pounds of water introduced into the furnace per ton of iron produced. It is not difficult to imagine that such a quantity of water breaking up into its components, hydrogen and oxygen, and entering into the blast furnace reactions will have a pronounced effect upon the quality of the iron in addition to its effect upon the utilizable heat available.

These points of difference have been reviewed simply to refresh our minds with how details of blast furnace operation might vary and still produce iron of the same analysis. Our purpose is to take these irons of like analysis, but totally different in nature of environment while being born in the blast furnace, and show by experiment in the foundry that the resultant physical properties of our cast irons made from these pig irons is mightily influenced by that physical character conferred upon the pig iron by these variations in blast furnace operation. In view of variations in so many factors affecting the result, it is appreciated that we cannot realize the ideal method of experimentation where only one factor is varied at a time. All we can hope is that there might be two or three factors having a big enough influence on our results to overshadow the effects produced by the remaining variables. So much for the manufacture of the raw material.

Nature of Pig Irons Revealed by Tests

The chemical analysis of the eleven casts of pig iron is given in Table 3.

Table 3

Compo- sition	Lot No.										
T.C.	1	2	3	4	5	6	7	8	9	10	11
	3.61	3.68	3.90	3.95	3.64	3.90	3.81	3.80	4.00	4.00	4.02
	3.90	...	...	...	...	...	...	...	...	...	...
Mn.	.81	.81	.87	.71	.81	.93	.87	.69	.79	.65	.61
P.	.204	.173	.187	.161	.187	.184	.161	.169	.167	.144	.106
S.	.032	.037	.022	.066	.037	.039	.043	.036	.047	.033	.044
Si.	2.50	2.50	2.45	2.34	2.59	2.44	2.70	2.50	2.33	2.63	2.42
	...	...	2.50	...	2.41	...	...	...	...	...	...

An attempt was made to get all samples of iron with silicon between 2.40 and 2.60 per cent. This was not quite realized, but the analyses shown would all be acceptable for No. 2X malleable pig iron. It will be noted that lot 4 contains .066 sulphur. This was selected as an "off" or "bad" heat of iron to note its effect upon the properties of the cast iron made from it. The spread



FIG. 3a—GRAPHITE DISTRIBUTION OF PIG IRON'S, LOTS 1 TO 5 INCLUSIVE UNETCHED $\times 25$



FIG. 3b—GRAPHITE DISTRIBUTION OF PIG IRONS, LOTS 6 TO 11 INCLUSIVE—UNETCHED $\times 25$

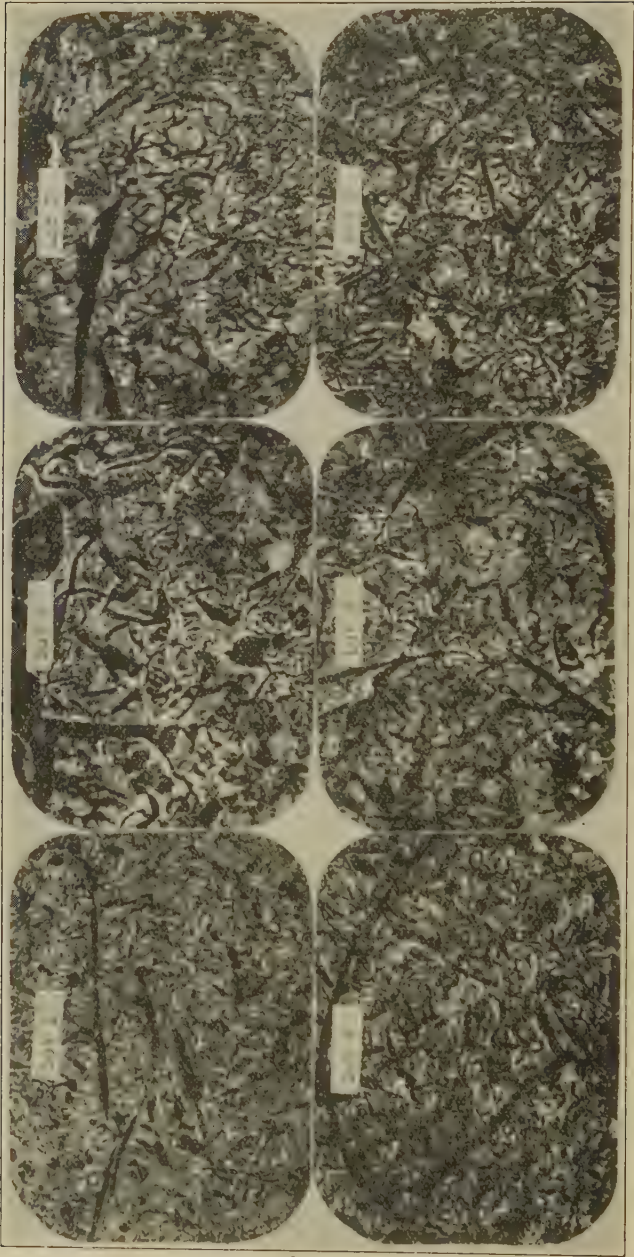


FIG. 3c—MICROSTRUCTURES OF PIG IRONS, LOTS 1 TO 5 INCLUSIVE—ETCH 5% NITAL— $\times 25$



FIG. 3d—MICROSTRUCTURES OF PIG IRONS, LOTS 6 TO 11 INCLUSIVE—ETCH 4% NITAL— $\times 25$

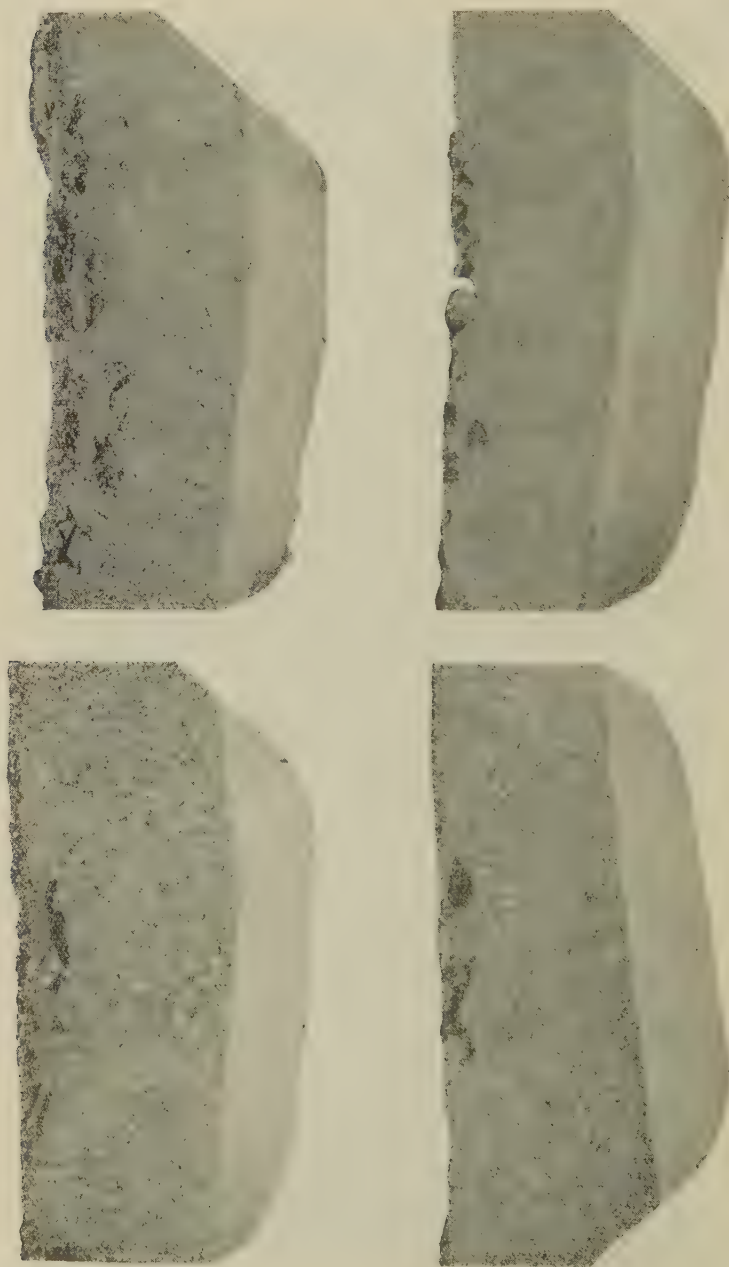


FIG. 4a—FRACTURE OF PIG IRON, LOT 1



FIG. 4c—FRACTURE OF PIG IRON, LOT 3

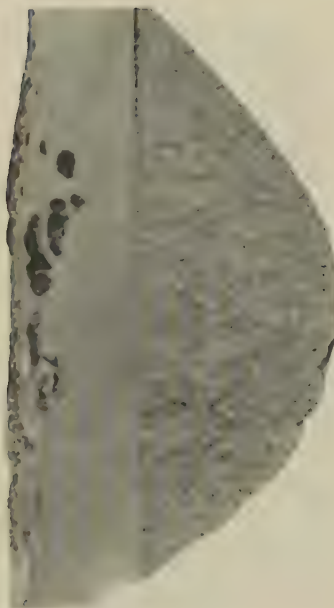


FIG. 4b—FRACTURE OF PIG IRON, LOT 2

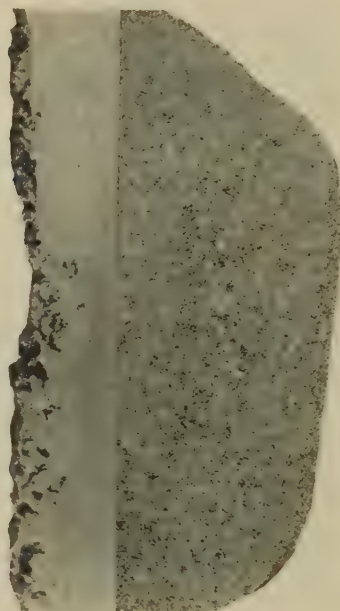


FIG. 4c—FRACTURE OF PIG IRON, LOT 5

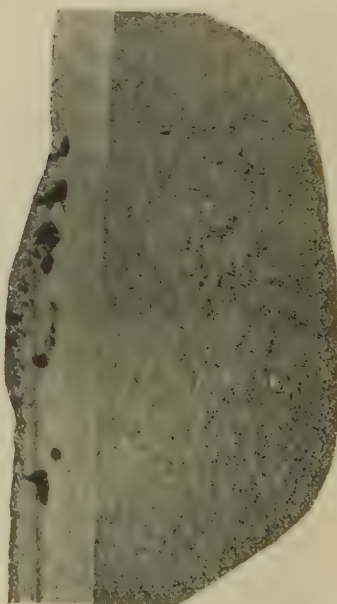


FIG. 4d—FRACTURE OF PIG IRON, LOT 4

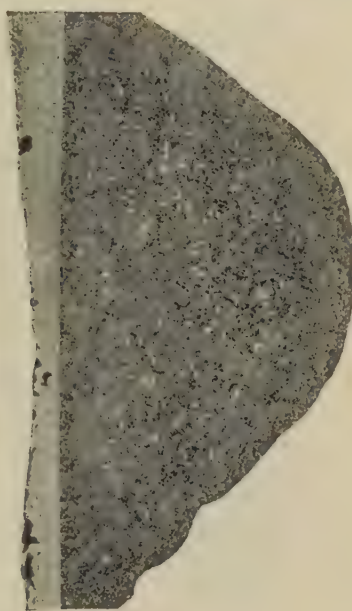
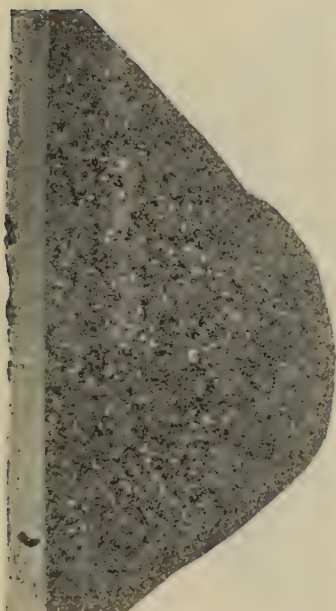


FIG. 4g—FRACTURE OF PIG IRON, LOT 7

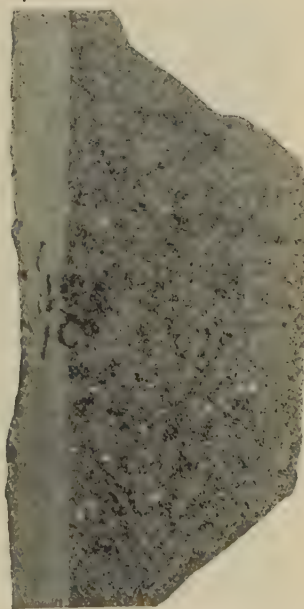
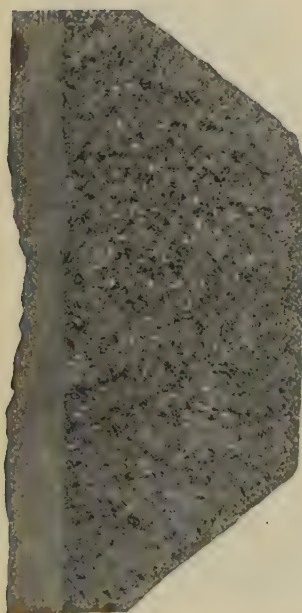


FIG. 4f—FRACTURE OF PIG IRON, LOT 6

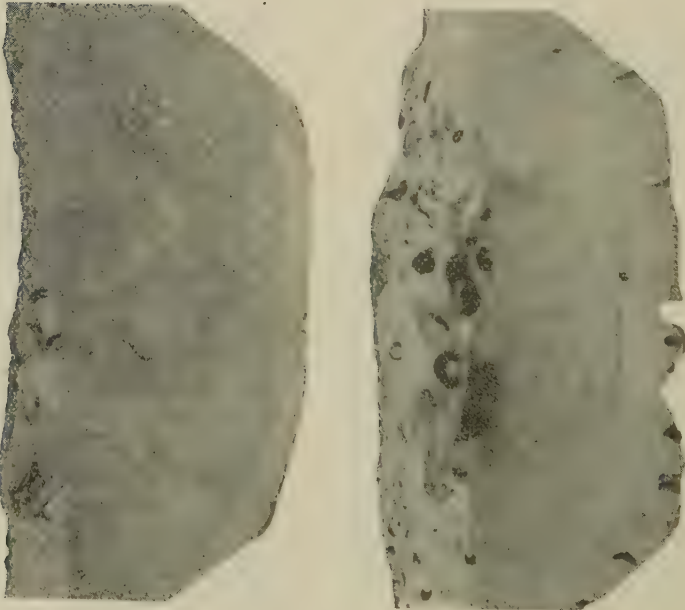


FIG. 4b—FRACTURE OF PIG IRON, LOT 8

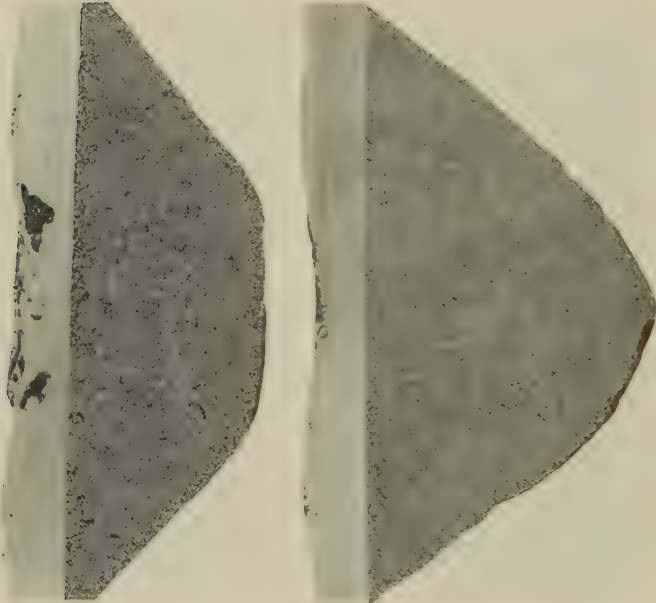


FIG. 4i—FRACTURE OF PIG IRON, LOT 9

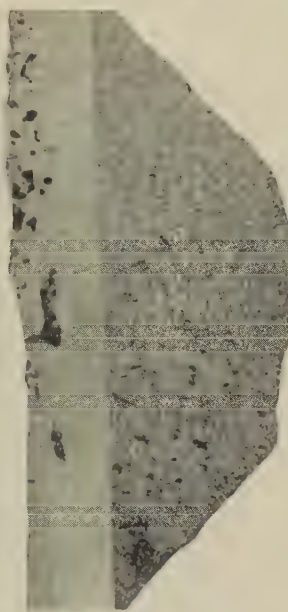
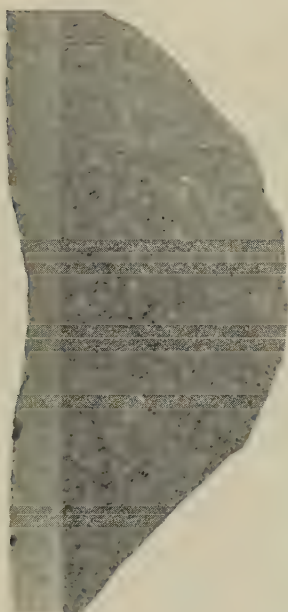


FIG. 4k—FRACTURE OF PIG IRON, LOT 11

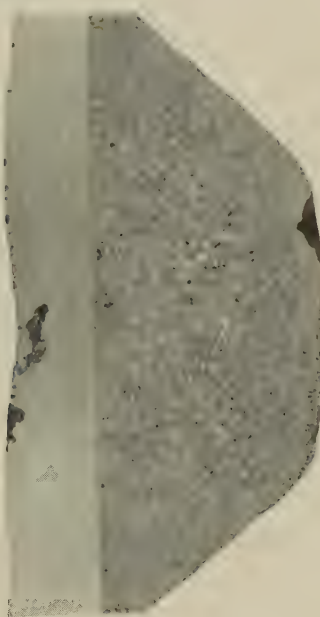


FIG. 4j—FRACTURE OF PIG IRON, LOT 10

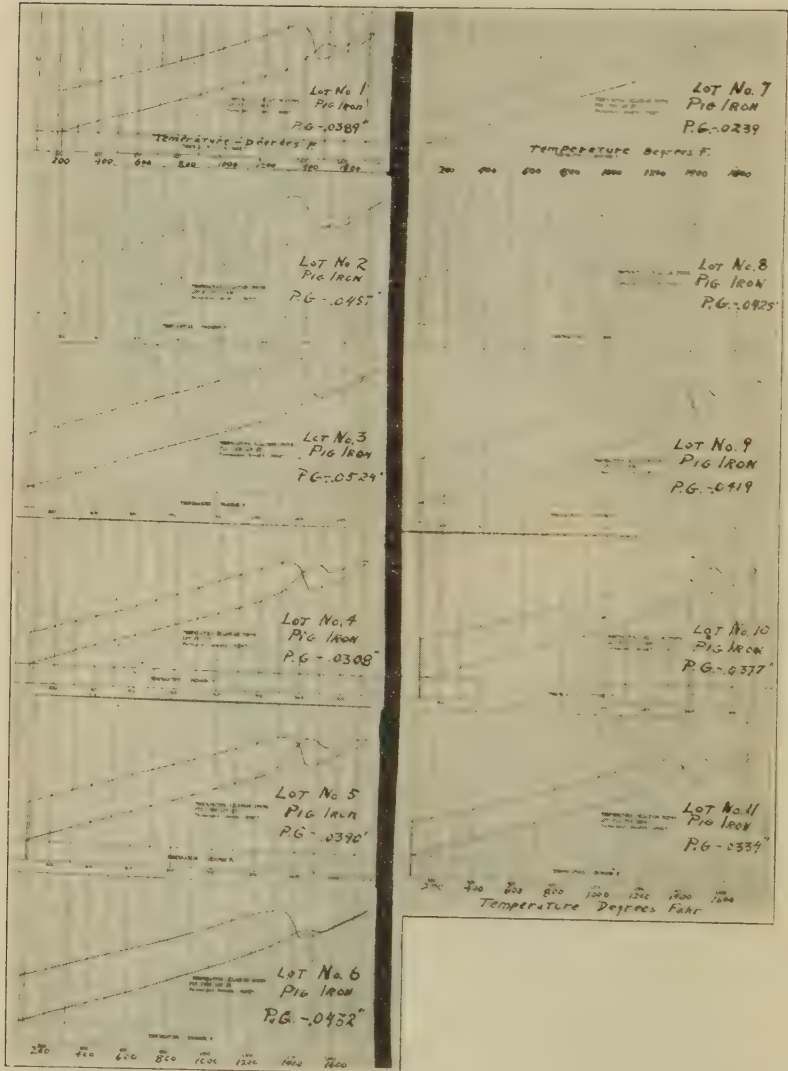


FIG. 5—DILATION CURVES PIG IRONS, LOTS 1 TO 11—P.G. INDICATES PERMANENT GROWTH

covered by the carbon contents is quite wide, reaching from 3.61 to 4.02 per cent.

Microstructure

The microstructure of the various lots of pig iron is shown in Figs. 3a to 3d. Two distinct types of microstructure were observed. An example of one type is that exhibited by lot 1 pig iron, where the primary graphite flakes are short and thick with secondary flakes fairly large and far apart. The other type is exhibited by lot 7 pig iron, in which the primary flakes are long, thin, straight, and far apart with a matrix of very finely divided close packed secondary flakes.

Fracture

Photograph of fractures of pigs from various lots are shown in Figs. 4a to 4k.

The types of fracture range from coarse open black fracture with large primary graphite flakes down to fine-grained gray fracture, as well as intermediate types containing patches of the fine-grained structure throughout a coarse black structure.

Dilation Characteristics

Reproductions of the dilation temperature curves for the various pig irons are illustrated in Fig. 5.

It appears that there is a beginning of graphite precipitation around 1250 to 1300 degrees Fahr. upon heating, which causes an increased rate of expansion until the Ac point is reached between 1450 and 1500, at which point the combined carbon goes into solution in the iron, causing a contraction before expansion is resumed. Upon cooling, more graphite precipitates out causing a marked expansion in the neighborhood of 1425 to 1450 degrees Fahr. This expansion is permanent and persists down to atmospheric temperature. The great difference in dilation characteristics of various pig irons occurs in the magnitude of these expansions upon heating and cooling. For example, curve for lot 3 pig iron shows a very small expansion upon heating and a large expansion on cooling through the Ar range resulting in a permanent growth of .052 inches. On the other hand, curve for lot 7 shows a large expansion upon heating

between 1200 and 1500 degrees Fahr. and a comparatively small expansion upon cooling through the Ar range resulting in a permanent growth of only .024 inches.

Curves for other lots of pig iron show characteristics intermediate between these extremes. In study of dilation characteristics of cast irons made from those pig irons we shall see the relation between pig iron and cast iron dilation characteristics.

General Method of Procedure

As already mentioned, these pig irons of known history were obtained in approximately 75 ton lots and studied one at a time by converting into cast iron and measuring various properties of that cast iron. The investigation of each lot of pig iron lasted about three weeks.

Each day there were melted about 7 to 8 tons of iron made from raw materials, 50 per cent of which was of the pig iron to be tested and the remainder of return scrap from the day before, silvery iron and steel. Most of the 7 or 8 tons of iron melted per day was cast into automobile engine flywheels. The metal used for the series of test bars poured was taken after 14 ladles of 500 pounds each had been drawn from the cupola and poured into flywheels. This precaution was taken to allow time for the cupola operation to come to more or less equilibrium after starting up effects had disappeared.

All test bars were poured as near as possible between 2425 and 2500 degrees Fahr. measured on metal running from a 500 pound ladle with a Leeds and Northrup optical pyrometer. The procedure was to obtain a full ladle and pour from it one flywheel to enable the making of a temperature determination. The first flywheel from a ladle was usually in the neighborhood of 2550 to 2575 degrees Fahr. Successive flywheels were then poured until the temperature of the metal had dropped to 2510 degrees Fahr. then the ladle was moved over to the row of test bar molds and these were poured until the metal had dropped to 2425 degrees Fahr. below which temperature the metal was used again for flywheels. In this manner all the test bars were obtained from two successive ladles near the middle of the 7½ ton cupola heat. Sample for chemical analysis was taken from each of the two ladles used to pour test bars.

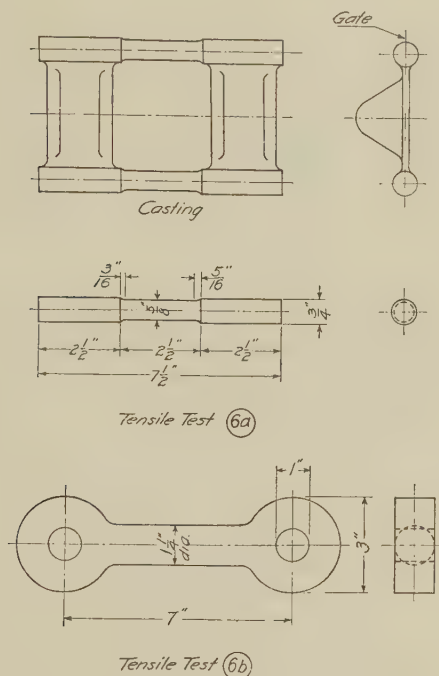


FIG. 6A—TEST SPECIMENS USED DURING INVESTIGATION

Method of Conducting Tests

The sketches of Figs. 6A to 6D, inclusive, show the various test bars employed.

Figs. 6a and 6b show the tensile test bars. These were molded in a horizontal position in green sand. The $\frac{5}{8}$ inch diameter bars cast in pairs were fed from two shrink bobs placed so as to join the shanks of the test bars. The $1\frac{1}{4}$ inch test bars were fed from a heavy riser. The bars were pulled with their cast surface intact. The transverse test bar was made as described in A. S. T. M. Standard A48-18, except that green sand was used. The transverse bars were cleaned by brushing and were loaded transversely between 12 inch centers.

Fig. 6c shows the step bar for hardness determinations. Because Brinell hardness is the standard of hardness in our found-

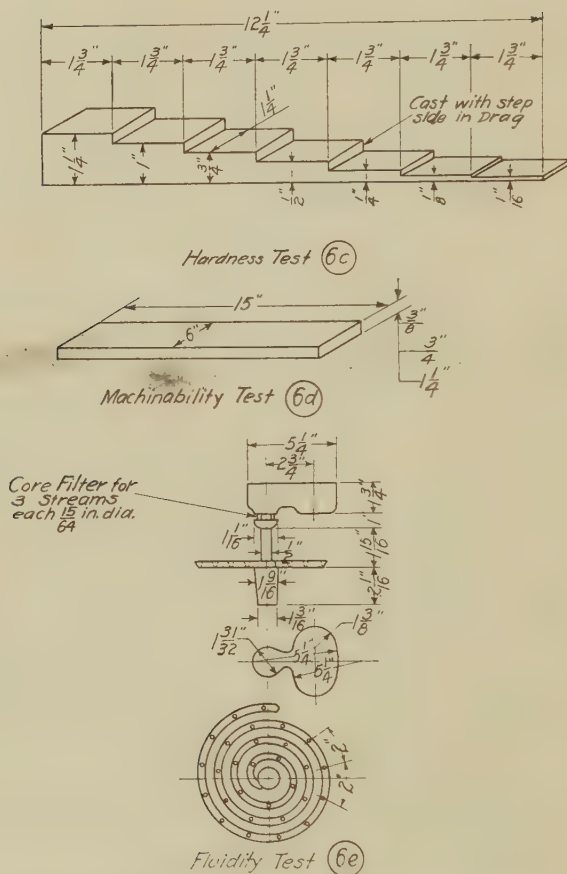


FIG. 6B—TEST SPECIMENS USED DURING INVESTIGATION

dries it was chosen for hardness determinations. This test bar was cast in a dry sand core mold, horizontal with the step side of the casting in the drag. This is an important factor because by casting this bar with the steps in the cope very different hardnesses result.

Fig. 6d shows three slabs of different thickness which were used for the machinability test. This test consists of determining the power required to remove metal $\frac{1}{8}$ inch deep with .027 inch

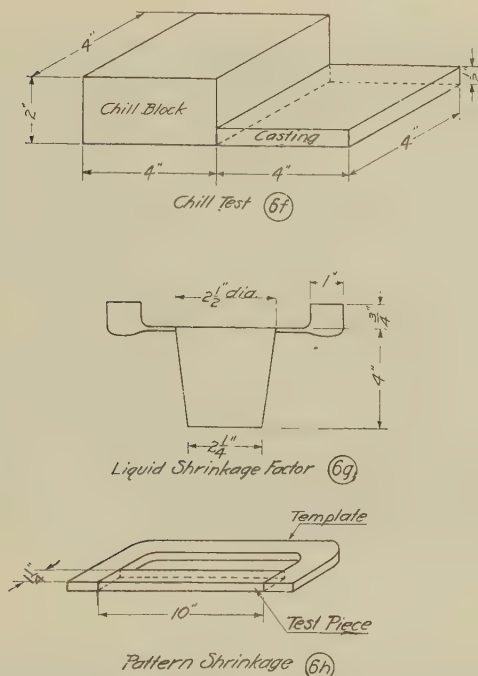


FIG. 6C—TEST SPECIMENS USED DURING INVESTIGATION

feed at the rate of nine strokes per minute. This test was conducted on a shaper as shown in Fig. 7. The power curve obtained is shown in Fig. 8. The dimension C is taken as the power required for the cut. The various cast irons were compared with respect to this quantity. Hardness determinations were made on these slabs as well to determine effect of section size on hardness when cast in green sand.

Fig. 6e shows the fluidity test bar which was copied from that described by C. Curry.³ This bar was cast in a dry sand core.

Fig. 6f shows the mold for testing tendency to chill. The 4" x 4" x 1/2" specimen cast in green sand against the steel block

³Test Bars to Establish the Fluidity Qualities of Cast Iron—C. Curry. Transaction of A. F. A., Vol. XXXV.

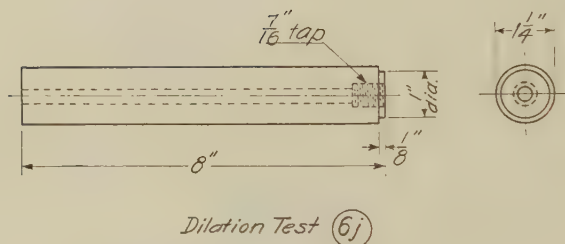
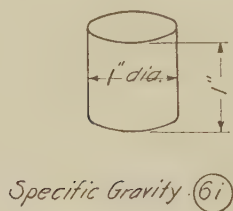


FIG. 6D—TEST SPECIMENS USED DURING INVESTIGATION

was broken perpendicular to the chilled side after cooling to atmospheric temperature and measurement made of the total penetration, as well as the depth of that part of the chill which contained no gray spots.

Fig. 6g shows the test sample used to measure the volume shrinkage. This was provided with a very thin gate and runner to the riser, so that there would be no feeding after the mold was filled. The mold was made in dry sand core and very carefully measured before closing.

The resultant casting usually contained a shrinkage depression at the top.

Measurements of the volume of the casting and volume of the shrinkage depression were made by noting the weight of water displaced by immersion of the casting (1) as cast and (2) with the shrinkage cavity filled with paraffin. This gave the total volume shrinkage compared with the original mold and also the volume occupied by the pipe.



FIG. 2b.—RECORDER FOR MACHINABILITY TEST—X IS POWER CURVE OF FIG. 8

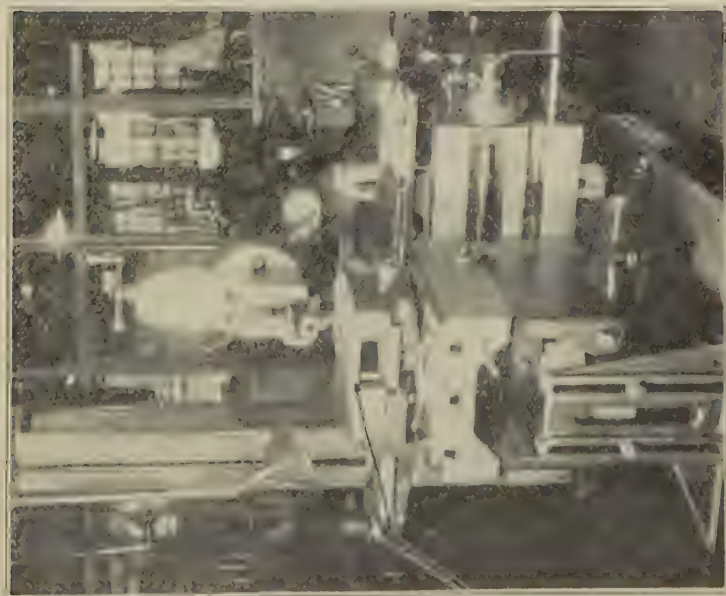


FIG. 2a.—MACHINABILITY TEST—X IS SLAB SPECIMEN

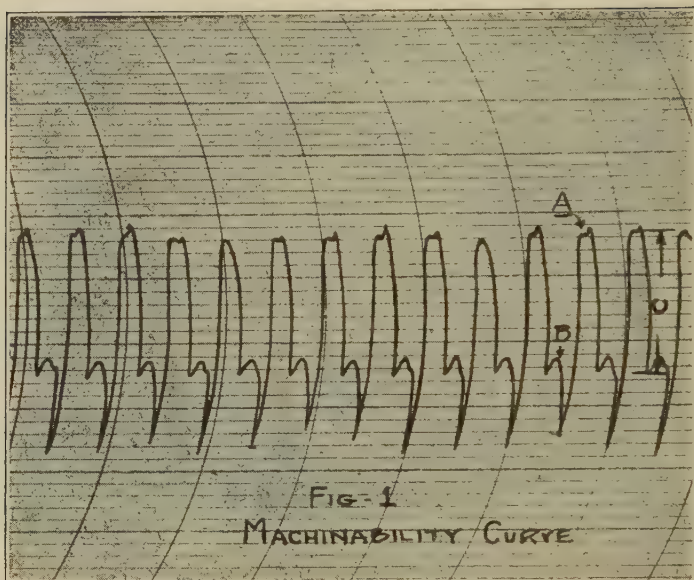


FIG. 8—POWER CURVE OF MACHINABILITY TEST—DIMENSION C IS TAKEN AS MEASURE OF POWER REQUIRED FOR CUT

Fig. 6h shows the pattern and the U template used for the determination of linear shrinkage. This casting was poured into a dry sand core mold.

Fig. 6i shows the size sample upon which density determinations were made. This sample was cut from the lower half of the transverse test bar.

Samples for microstructure were taken from the $1\frac{1}{4}$ and $\frac{1}{2}$ inch section of the step bar poured in core sand and from the $1\frac{1}{4}$ and $\frac{3}{8}$ inch machinability slabs poured in green sand.

Dilation Test

Dilation test samples shown in Fig. 6j were made from a bar of the same size as the bar on which transverse tests were

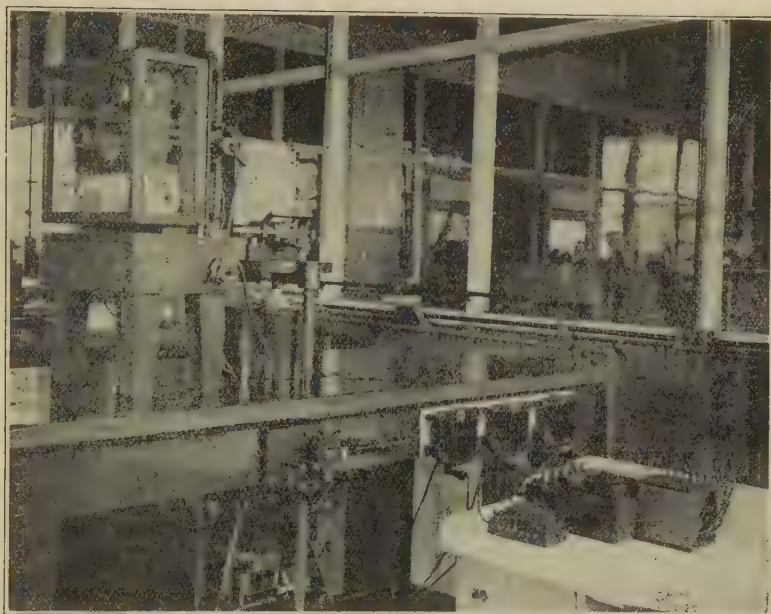


FIG. 9—DILATOMETER LAYOUT

made. The dilatometer, shown in Fig. 9, consists of a furnace wound with three separate resistors to facilitate temperature control throughout the length of the sample. Dilation of the specimen is translated through suitable mechanism to a roll of paper wound around a drum which is turned by the automatic Leeds and Northrup temperature recorder which is connected to the central couple of three thermocouples inserted in a hole bored through the center of the test specimen having their junctions near the two ends and the center of the test bar respectively. Having once determined the setting of the rheostats controlling the current in the furnace resistors so that the temperature at all three points increases at the same rate, the record of temperature and dilation is obtained automatically.

Correlation of Test Results

After completing all the tests, a great deal of work was done to relate the test results with operating data. Curves were

plotted between test results and values for operating circumstances which seemed as though they should be related and also between values which seemed to have no relation.

All the graphs in which the plotted data showed some resemblance to a definite trend are shown. It is fully appreciated that each one of the tests made might have been developed to a greater degree of refinement, but had we started to accomplish that, the thing we have tried to accomplish here would have been postponed indefinitely pending the ultimate refinement of each individual test.

We have assumed that an average obtained from a number of tests upon cast irons made from the same pig iron will give us a result that is truly representative of that cast iron just as much as a highly refined test where every influencing factor is accurately controlled. After all, we are looking for the manner in which these different pig irons manifest themselves in production foundry results, therefore, it is logical to draw our conclusions from the results obtained on test bars, the manufacture of which is attended by the conditions prevalent in a well controlled production foundry.

These results have shown us trends produced by certain causes. The sequel to this investigation should be one where the major causes of variation found in this work would be held constant in order that the effect of some of the minor causes might be studied.

Discussion of Test Results

Chill Test

The depth of chill resulting from casting iron against a block of iron or steel is usually considered to be dependent upon the silicon and carbon content. The values obtained for depth of chill in this investigation were plotted against silicon content and also against silicon content plus carbon over 3.00 per cent, but the points gave no indication of a relation between chill depth and analysis within the range studied.

Depth of chill was then plotted against grains of moisture per cubic foot of cupola blast, plus one-half the moisture in the blast furnace blast. The latter was added because 50 per cent of the cupola charge consisted of pig iron which was assumed to carry

with it the chilling tendency if any caused by the presence of water in the blast of the furnace in which it was made. This relationship is shown in Fig. 10.

The conclusion to be derived from this graph is that high moisture content of the cupola blast produces a heavy chill. It also indicates that with low moisture content in the blast, other influences may act to produce a heavy chill. It is important to note that no low values for depth of chill were obtained when the moisture content was high. It is suspected that degree of oxidation of the pig iron in the blast furnace and of the gray iron in the cupola might be an important cause of formation of white iron, but this could not be studied, due to lack of suitable methods for determining presence of oxides. There are probably other influences which might cause a deep chill in spite of low

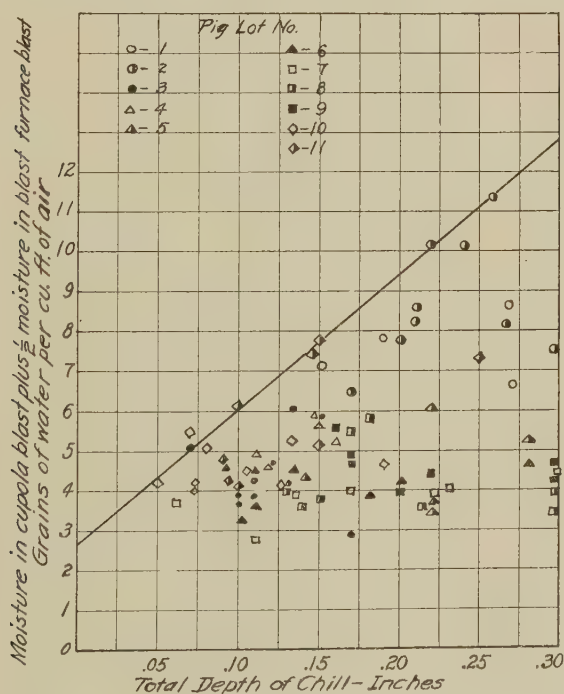


FIG. 10—RELATION BETWEEN DEPTH OF CHILL AND HUMIDITY OF BLAST

moisture content in the blast. These other causes are responsible for failure of the points to lie on a single straight line.

Combined Carbon

It would seem logical to suppose that the amount of combined carbon present in cast iron might be determined and controlled by the same causes which affect the depth of the white iron layer produced when iron is cast against a chill. The amount of combined carbon was determined in the $\frac{3}{8}$ inch thick machinability slab cast from each heat run in this investigation. These combined carbons were plotted against the grains of water per cubic foot of cupola blast, plus one-half the grains of water per cubic foot of blast furnace blast. The resulting graph is shown in Fig. 11. Where there are as many uncontrollable variables existing as have already been previously enumerated, it is not reasonable to expect the points defined by any two factors to lie

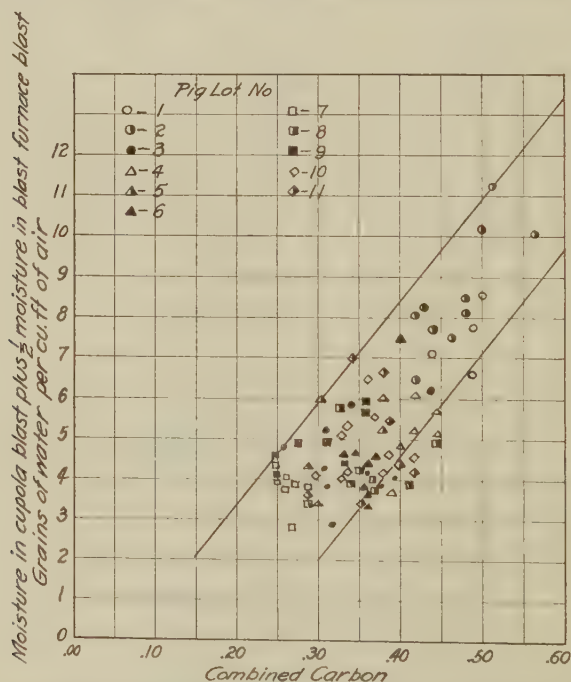


FIG. 11—COMBINED CARBON AS AFFECTED BY MOISTURE IN BLAST

close to a single line. For any given degree of blast humidity the combined carbon in the iron might vary between limits, depending possibly on degree of oxidation of iron, casting temperature, rate of cooling, silicon content, etc. Therefore the graph between combined carbon and blast humidity shows the points all falling in a band instead of along a single line. The occurrence of the points shows a trend from low combined carbon and low humidity to high combined carbon and high humidity. The width of the band signifies the potency of factors other than humidity to affect the combined carbon. Humidity is apparently the most important of the influences so we cannot determine how much these other factors affect combined carbon until we can control the humidity.

Shrinkage Cavity as Affected by Rate of Ore Reduction in Blast Furnace

On page 100 attention was called to the great variation in the rate of travel of the burden through the blast furnace. Since the process of converting iron oxide to iron requires a certain amount of time, it is not difficult to imagine that too rapid a passage of iron through the furnace will result in incomplete reduction of the ore causing the pig iron to contain some unreduced oxides.

It is a well known fact that the size of the pipe in the top of steel ingots is greatly affected by the presence of dissolved oxides and gases. A completely deoxidized steel will form a large deep pipe at the center and top of the ingot, while a gassing or incompletely deoxidized steel will show very little pipe, due to the formation of small voids by eviction of gases from solutions throughout the ingot during solidification, totalling in volume the large pipe which would form if the steel were deoxidized completely before casting.

Working on the theory that oxides dissolved in the pig iron, due to incomplete reduction of the ore, might increase with the speed of ore travel and thus decrease the size of pipe or shrinkage cavity in the casting, the rate of travel of the ore through the blast furnace was plotted against the size of shrinkage cavity in the top of the volume shrinkage test bar. This relationship is

shown as Fig. 12. Each point represents the average shrinkage cavity for all cast irons made from one kind of pig iron.

The arrangement of the points indicates that our surmise was correct. It is hard to decide which property is more desirable—that possessed by the completely reduced iron which results in better ability to feed from the riser and gates to the casting, or that of the oxidized iron which solidifies without shrinkage cavities unassisted by feeding from gates or risers. The foundryman must decide this point, depending on his own particular needs.

The shrinkage cavities were measured in castings poured at 2450 degrees Fahr. Castings poured from the same iron at 2275 degrees Fahr. showed no shrinkage cavity at all. The amount of over-all volume contraction of the various cast irons poured

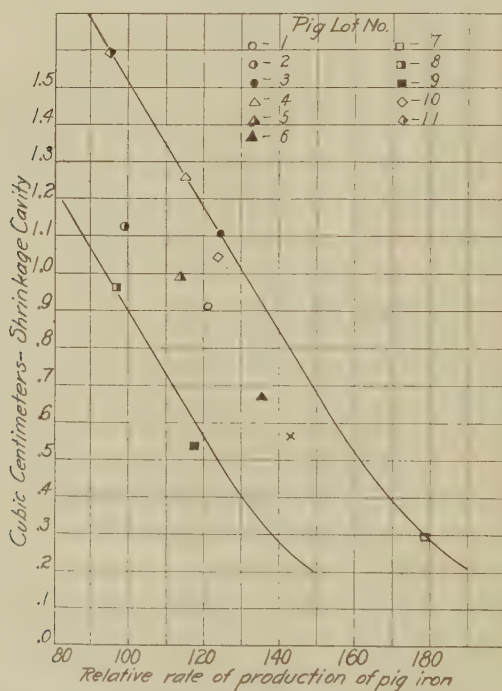


FIG. 12—POUNDS OF IRON PRODUCED PER HOUR PER SQUARE FOOT AREA OF BLAST FURNACE AT MAXIMUM DIAMETER—SHRINKAGE AS AFFECTED BY RATE OF ORE REDUCTION IN BLAST FURNACE

at 2450 degrees Fahr. varied from 3.47 per cent average of irons made from lot 3 pig to 5.16 per cent average of irons made from lot 1 pig. No data were obtained showing the cause for this variation. It is presumably related to oxide content, total carbon, combined carbon content, etc. It must be understood that this paper refers only to shrinkage cavities obtained with a given size and shape of casting poured under certain conditions. It must not be presumed that rate of blast furnace travel in making pig iron is being offered as an explanation for shrinks of all kinds. These data are a statement of results obtained under the particular conditions of our test and not necessarily related to other types of shrinkage. The truth we are trying to establish is that blast furnace operating circumstances confer character upon pig iron which persists through subsequent melting in the cupola and affects definitely the properties of the cast iron it makes.

If it is desired to make pig iron possessing properties associated with rapid travel through the furnace, it can be accomplished by using a fast burning coke and plenty of air. This will cause rapid travel allowing short time for the reduction of the ore. Whether or not this type of iron is desired, it is obviously an advantage to use a fast burning coke because it will respond in rate of burning to the rate at which air is supplied; thus offering an opportunity of positive control to the operator, who then can regulate his speed of ore travel at will by speeding up or slowing down the blast. With a slow burning coke this control is impossible. For the best control of the furnace the combustibility test described in the appendix to this report should be supplemented with a rumble test which will permit selection of coke with uniform resistance to the grinding action in the furnace; thus keeping the charge open for free passage of the furnace gases. At one of the furnaces where we obtained pig iron the rumble test alone was being used with success for controlling the quality of the coke.

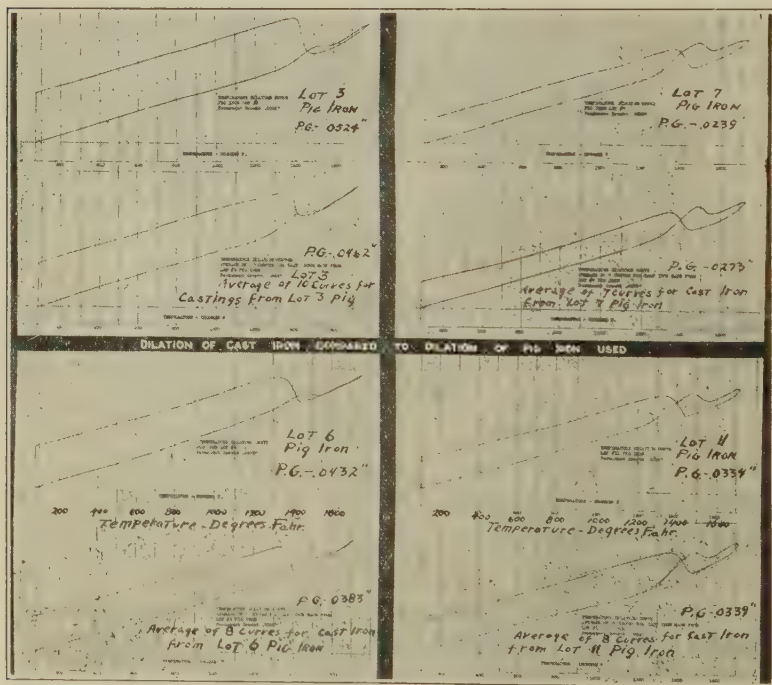
Thus we see that the quality of the coke has a great influence on several phases of blast furnace operation. It influences

1. Rate of burden travel which determines tonnage production of pig iron.

2. Time of ore in the furnace which influences the shrinkage characteristics of the iron.
3. Amount of air supplied per ton of iron made.
4. Amount of water passing through furnace per ton of iron made.

Dilation Characteristics

Additional evidence that the properties of a pig iron are conferred upon the cast iron made therefrom was obtained in comparing the shape of dilation temperature curves of pig irons and cast irons. Curves, Fig. 13, show the dilation temperature curve of various pig irons compared with the average curve for all cast irons made from that pig iron. It will be seen that



the dilation characteristics of the pig iron determine those of the cast iron made therefrom.

As previously mentioned, the dilation curves for different pig irons differ in amount of expansion and contraction in approaching and passing through the Ac range and in the amount of permanent growth occurring on cooling. It is interesting to note (Fig. 13) that large permanent growth is associated with a small expansion and contraction in passing through the Ac range and as this latter phenomena increases in magnitude, the permanent growth of the sample decreases. Note the variation from .052 inch permanent growth of sample from pig lot 3 down to .024 inch permanent growth for sample from lot 7. In showing the average dilation curve for cast irons made from pig iron lot 11, dotted lines are drawn in to show the maximum and minimum variation from the average. All curves obtained from eight different heats made from pig iron lot 11 fell between the dotted lines shown.

The similarity between curves for pig iron and curves from cast iron made from that pig iron is quite conclusive evidence that pig iron quality persists through the cupola melting operation and shapes the properties of the cast iron.

As a subject for further research, I would recommend the study of the relation between time of burden in blast furnace, liquid shrinkage, and dilation characteristics in causing cracked castings as being one particularly liable to yield interesting and valuable results.

Machinability

Values of power required for machining the various cast irons plotted against hardness showed a general relation of better machinability for softer irons, but there was considerable difference in machinability of different cast irons of the same hardness. Resorting again to the moisture content of the blast, machinability of the $\frac{3}{8}$ inch slabs was plotted against moisture content of the blast, plus one-half of the moisture content of the blast furnace blast during the manufacture of the pig iron used. The result is shown in Fig. 14. The majority of the points suggest better machinability for dryer blast. The points above the

band which show better machinability than would be expected from their corresponding moisture content are mostly cast irons made from pig iron made while the furnace was operating very slowly, therefore, presumably resulting in complete reduction of the ore.

On the other hand, a good many points below the band showing poorer machinability than is warranted by their value of moisture content were made from pig iron produced in a fast travelling furnace producing presumably incompletely reduced iron. The conclusions that these data suggest then are that

1. Machinability is improved by removal of the water from the blast.
2. Well deoxidized pig iron makes cast iron which machines better.

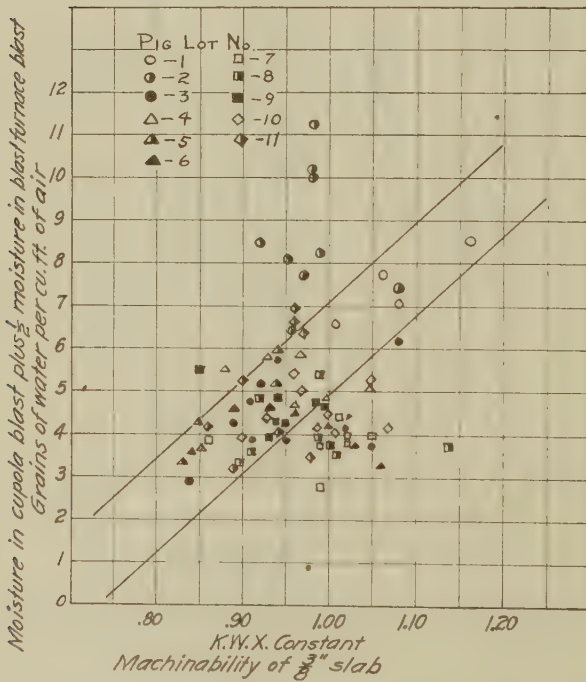


FIG. 14—MACHINABILITY AS AFFECTED BY MOISTURE IN BLAST

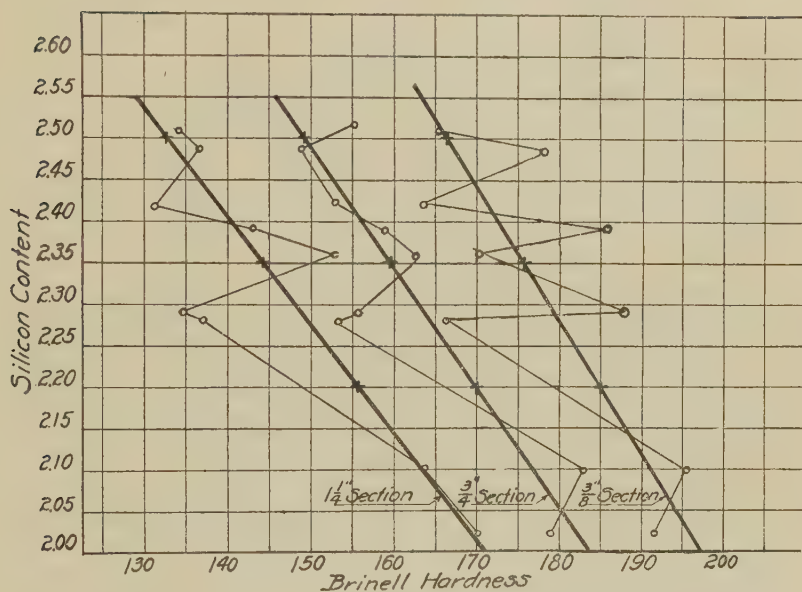


FIG. 15—INFLUENCE OF SILICON ON HARDNESS OF SLABS CAST IN GREEN SAND—NINE HEATS OF IRON MADE FROM LOT NO. 3 PIG IRON

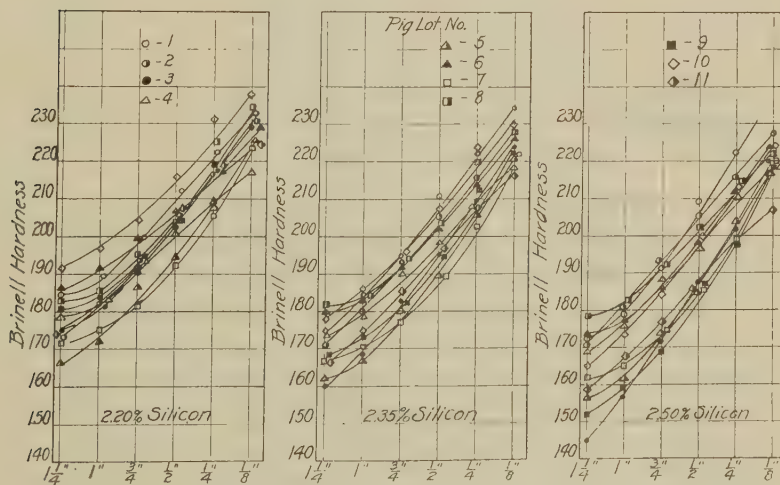


FIG. 16—EFFECT OF SIZE SECTION AND SILICON CONTENT ON HARDNESS OF IRONS MADE FROM VARIOUS PIG IRONS—RESULTS ARE FROM STEP BARS POURED IN DRY SAND CORES

3. Pig iron produced too fast makes cast iron which is difficult to machine.
4. When referring to cast irons made from the same pig iron and under like cupola conditions softer irons machine better.

Hardness of Cast Iron as Affected by Section Size and Silicon Content

The original program of investigation assumed we would be able to make cast iron consistently within a narrow range of silicon content. We discovered the interesting fact that it was possible to do this while using some pig irons, but with the use of other pig irons the silicon varied considerably. This variation cannot be attributed to any variation of the silicon in a given lot of pig iron, because each lot of pig iron obtained was all from one cast and analysis of several pigs from one lot showed very close agreement with not more than .11 per cent variation. Table 4 shows how the silicon content varied in the cast irons made from those pig irons.

Table 4

Pig Lot No.	No. of Cast Iron Heats	Silicon Content, Per Cent	Variation
1	4	2.37 to 2.53	.16
2	9*	2.01 to 2.51	.50
3	10	2.13 to 2.35	.22
4	6	2.15 to 2.48	.33
5	5	2.33 to 2.54	.21
6	8	2.15 to 2.43	.28
7	7	2.36 to 2.42	.06
8	8	2.19 to 2.43	.24
9	7	2.13 to 2.38	.25
10	9	2.20 to 2.50	.30
11	8	2.20 to 2.43	.23

The reason why cast irons made from lot 6 pig iron are so uniform in silicon content and why cast irons made from lot 2 pig vary so much in silicon content is not apparent.

The variation in silicon content was used to study the hardness variation. Graphs were plotted between Brinell hardness versus silicon content for each group of cast irons made from one pig iron. Values of Brinell hardness were plotted for $1\frac{1}{4}$, $\frac{3}{4}$ and $\frac{3}{8}$ inch sections cast in green sand, and $1\frac{1}{4}$, $1\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$ inch sections cast in dry sand core. All curves obtained

*Combined carbon determination was made on one additional heat from lot No. 2 pig, making 10 points for lot No. 2 on Fig. 11. Test bars for other tests were not cast in this heat.

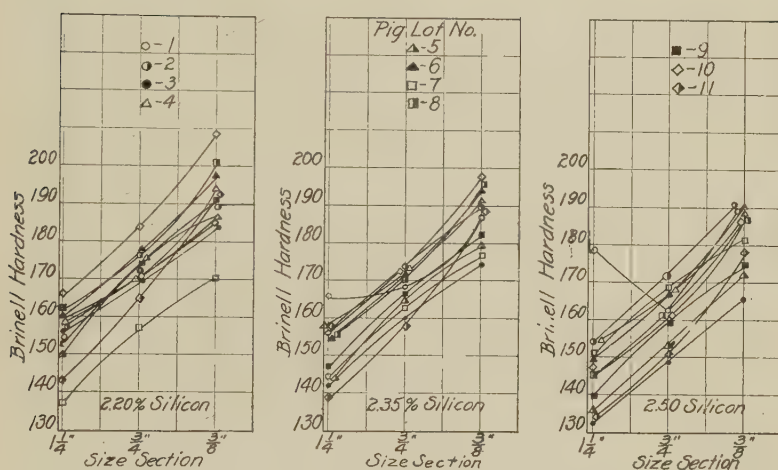


FIG. 17—EFFECT OF SIZE OF SECTION AND SILICON CONTENT ON HARDNESS OF IRON MADE FROM VARIOUS PIG IRONS. RESULTS ARE FROM SLABS CAST IN GREEN SAND

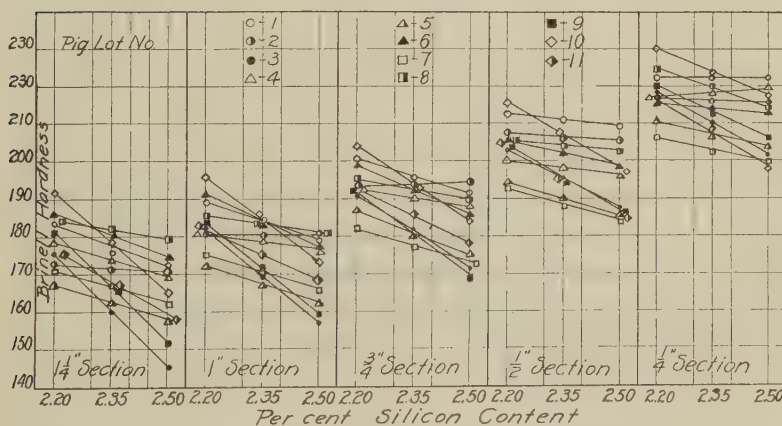


FIG. 18—EFFECT OF SILICON ON HARDNESS OF CAST IRON MADE FROM VARIOUS PIG IRONS. RESULTS FROM STEP BARS POURED IN DRY SAND CORES

between silicon content and Brinell were very irregular. See graph of Fig. 15. The zigzag line connects the points representing irons of like section. These zigzag curves show a trend represented by the heavy line drawn as an average of the points on the zigzag line. The heavy line is assumed to be the line along which the points would all lie if we could eliminate all variables other than silicon content. The heavy line or average silicon hardness curve obtained in this way will be used as the basis of comparison with cast irons made from other pig irons. By picking values for hardness from these average curves it will be possible to compare hardness with reference to a given silicon content of cast irons made from the various pig irons. On Fig. 16 are shown curves giving the relation between hardness and size section referred to 2.20, 2.35 and 2.50 per cent silicon for iron cast in dry sand core. On Fig. 17 this relation is given for iron cast in green sand. The most striking fact presented by these curves is the big variation in Brinell hardness for irons of like silicon content and size section. Here is iron of 2.20 per cent silicon made from pig iron lot 3 cast in $1\frac{1}{4}$ " section in dry sand, giving a hardness of 165, while iron of the same silicon

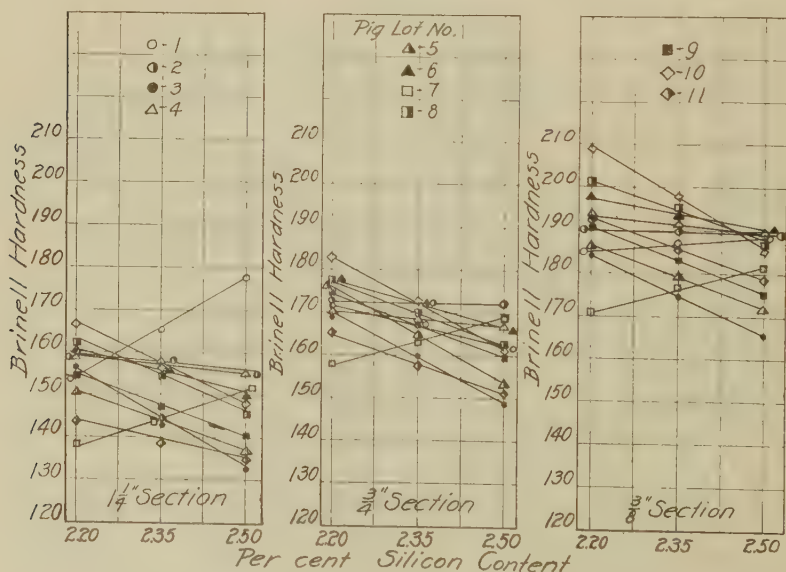


FIG. 19—EFFECT OF SILICON ON HARDNESS OF CAST IRONS MADE FROM VARIOUS PIGS—RESULTS FROM SLABS CAST IN GREEN SAND

made from pig iron lot 9 and also cast in $1\frac{1}{4}$ inch section in dry sand, is 192 hard, a difference of 28 points. The difference is greater in irons containing higher silicons. Iron of 2.50 per cent silicon made from pig lot 7 gives 178 hardness in $1\frac{1}{4}$ inch section cast in dry sand, while iron made from pig lot 4 cast under the same conditions gives 145 Brinell, a difference of 33 points. Variations of the same degree exist in cast irons poured in the green sand molds. What this difference is caused by is a matter of speculation. The following factors are suggested as possible causes.

1. Rate of production of pig iron which affects the amount of oxides in the pig iron.
2. Amount of water in blast per ton of pig iron produced and in cupola blast.
3. Composition of cupola atmosphere.

Another interesting relationship is the effect of silicon upon hardness of iron in a given section size. This comparison is given in graphs of Figs. 18 and 19. Take for example the effect of silicon on the hardness of irons cast in $1\frac{1}{4}$ inch section in dry sand. In irons made from pig lot 9 an increase of silicon from 2.20 to 2.50 per cent decreases the hardness 29 points on the other hand the same difference of silicon in irons made from pig, lot 8, causes a drop of only 5 points in Brinell hardness. Other irons show results in between these two extremes. The same is true of other section sizes and also for irons poured in green sand. In green sand it will be noted (Fig. 19) that in some cases there was actually an increase in hardness with higher silicon content. No explanation is offered for this phenomena. The results are simply given as they were obtained.

After results had been obtained from the first six lots of pig iron, the evidence pointed to the fact that pig iron tapped from the blast furnace at a high temperature made softer cast iron than pig iron tapped at a low temperature. Also a hot iron made with a basic slag made cast iron in which the silicon had a greater influence on hardness than in an iron made from pig iron made with an acid slag and tapped cold. The results of the remaining five heats of pig iron did not entirely confirm this theory.

Tensile Strength (Specimen $\frac{5}{8}$ -Inch Diameter as Cast)

As a means of comparing tensile strengths of the various cast irons on a uniform basis, tensile strength of the $\frac{5}{8}$ -inch diameter as cast bars have been plotted against a composite factor of total carbon plus one-third silicon. The graph of Fig. 20 shows this relation. The points do not fall along a single line, a fact which has been repeatedly observed in all of this work because of the fact that there is probably no property of cast iron which is influenced by or a result of one and only one cause. It is to be expected, therefore, that the points occupy a zone of a width depending upon the magnitude of effect of other factors. The trend indicates a decrease of tensile strength with increasing total carbon plus one-third silicon.

The center line is drawn to represent the average of this trend. Referring to this average line we are able to determine what tensile strength can be expected of an iron knowing its carbon and silicon content.

Referring each of the heats of cast iron to this grand aver-

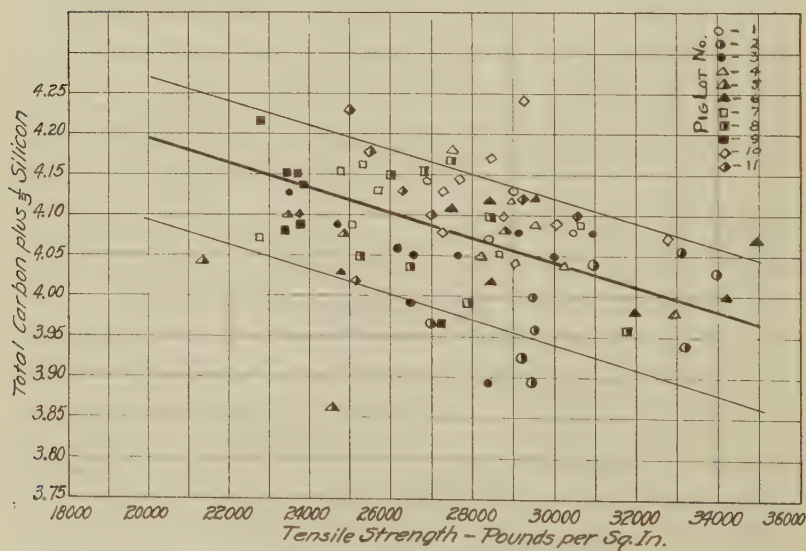


FIG. 20—EFFECT OF TOTAL CARBON AND SILICON ON TENSILE STRENGTH

age curve, we find that cast irons made from some of the pig irons have tensile strengths which fall below this average and that cast irons made from other pig irons have strength in excess of the average. The tensile strength of each heat was compared to the average tensile strength. For example, the tensile strength of cupola heat C-174 is 25,700 pounds per square inch with a $TC + \frac{1}{3}Si$ value of 4.13. The value of tensile strength on the average curve for a value of 4.13 for $TC + \frac{1}{3}Si$ is 24,500 pounds per square inch; therefore, the tensile strength of heat C-174 is 1,200 pounds per square inch over the average. Considering each

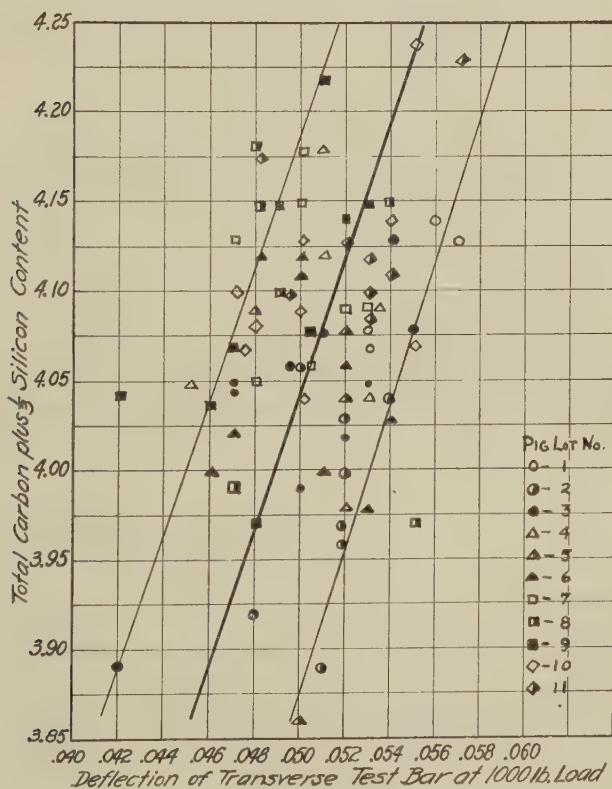


FIG. 21—RELATION BETWEEN RIGIDITY AND TOTAL CARBON PLUS $\frac{1}{3}$ SILICON

heat in this manner and averaging the heats made from each lot of pig iron gives us the data of Table 5.

Table 5

Cast Irons Made from Pig Lot No.	Lbs. per Sq. In. Tensile Strength Above or Below Average	Average Tensile Strength Re- ferred to, TC. + $\frac{1}{8}$ Si. = 4.05
10	+2660	32360
1	+2650	32350
4	+1560	31260
11	+1375	31075
6	+675	30375
7	+170	29870
8	—525	29175
9	—1780	27920
3	—2270	27430
2	—2845	26855
5	—5100	24600

What this difference in tensile strength is due to is not apparent from data obtained. This subject is worthy of the attention of future investigators.

Rigidity

The rigidity of cast iron is indicated by the deflection of the bar during the transverse test on the $1\frac{1}{4}$ -inch round arbitration test bar. Comparison of all the heats has been made on the basis of deflection at 1,000 pounds load. This factor has been plotted against total carbon plus $\frac{1}{3}$ silicon in Fig. 21. The points fall in a zone indicating decreasing rigidity with increasing TC + $\frac{1}{3}$ Si. The average curve was drawn as in the case of the tensile strength study and degree of rigidity above or below average determined for each heat and averaged for each group of cast iron made from one lot of pig iron. The results listed in Table 6 were obtained:

Table 6

Pig Lot No.	Average Deflection at 3500 lbs. Load for TC. + $\frac{1}{8}$ Si. = 4.05
7	.168
9	.169
8	.172
10	.172
4	.175
11	.176
3	.176
5	.177
6	.177
2	.186
1	.188

Specific Gravity

Specific gravity of the cast irons studied show a variation from 7.159 which is the average for cast irons made from lot 11

pig to 7.23 average for cast irons made from lot 4. It would seem logical that the denser irons would show bigger shrinkage cavities in the volume of shrinkage test bars but on the contrary irons made from lot 11 pig iron showed greater shrinkage than those made from lot 4.

It will probably be necessary to establish control of some of the many variables affecting the properties of our cast iron before we can establish a relation between specific gravity and factors determining its magnitude—such as oxygen content, other occluded gases, maximum temperature in blast furnace and cupola, with its effect on graphite shape and distribution, amount of combined carbon, silicon, total carbon, etc.

Fracture of Pig Iron

There is considerable variation in appearance of fracture of the various kinds of pig iron. The types of fracture range from coarse open black fracture with large graphite flakes down to fine-grained gray fracture as well as intermediate types containing patches of both. It is not apparent how these conditions are related to the properties of cast iron. The scruff on top of some pigs is apparently a function of the pig mold coating and can be completely eliminated by use of a dead burned dolomite mold coating. The only effect of scruffy pig iron upon production of cast iron is to increase the loss of iron by oxidation in the cupola.

Microstructure of Pig Iron

Two distinct types of microstructure were observed. An example of one type is that exhibited by lot 1 pig iron where the primary graphite flakes are short, and thick, with secondary flakes fairly large and far apart. The other type is exhibited by lot 7 pig iron in which the primary flakes are long, thin, straight and far apart with a matrix of very finely divided close packed secondary flakes. It is not clear from data obtained what the factors are controlling these structures or what effect they have on the properties of the cast iron made therefrom.

Microstructure of Cast Irons

The outstanding feature of the microstructure of the cast irons was the finer structure possessed by irons poured in the dry sand core molds. This indicates that the iron cools more rapidly in the dry sand core molds than in green sand molds. That this is true can be seen from a comparison of hardness of iron poured in the two kinds of mold. Iron poured in a dry sand core mold is consistently harder than that poured in green sand. The graphite flakes of iron poured in the green sand mold, are usually much larger due to the slower cooling of the iron. The structure of the iron poured in the dry sand core mold is very similar to permanent mold cast iron in which the graphite is arranged in a eutetic pattern in finely divided flakes. No relation could be detected between microstructures of pig iron and cast iron made from it.

Linear Shrinkage

In every cast iron studied but one, the linear shrinkage was .144 inches per foot.

Fluidity

The fluidity of the cast iron varied depending on the pig iron used. Iron made from lot 9 was most fluid. When poured at temperatures between 2425 and 2475 degrees Fahrenheit it ran 18.17 inches average around the spiral of the fluidity test bar.

Cast irons made from lot 6 pig iron were the least fluid. When poured between 2425 and 2475 degrees Fahrenheit the iron ran 13.99 inches average. The reasons for variation in fluidity are very obscure and this investigation has thrown no light on the question except to supply added evidence that fluidity is a variable quantity depending on other factors in addition to phosphorus, carbon and silicon content, and pouring temperature. It is suspected that per cent of oxide in the metal has a great influence on fluidity. As there is no satisfactory means of determining oxide content in cast iron, it is difficult to make a suitable study of the phenomena of fluidity.

General

In seeking causes for the variation in the effect of pig irons on the physical properties of cast iron, the pig irons investigated were analyzed for nickel, chromium, arsenic and titanium besides the regular elements. The spectrum obtained by producing an arc between two electrodes of the pig iron was studied to discover the presence of any other elements in quantities sufficient to influence the physical properties of the pig iron or cast iron. These tests furnished no useful information.

Summary and Conclusions

The investigation discussed in this paper strengthens belief in the idea that physical character of pig iron is greatly influenced by variations in blast furnace operation and that two pig irons may have almost identical chemical composition with regards carbon, silicon, manganese, phosphorus and sulfur but still be as far apart as the poles in physical properties.

Also it is quite definitely demonstrated that the physical characteristic of pig irons persist during remelting in the cupola and greatly influence the physical properties of the cast iron made therefrom.

The data collected and tests conducted show that two things are responsible for a number of variations in blast furnace operation and resultant properties of pig iron. These two things are quality or combustibility of coke and amount of water in the blast. The influence of these variables is just as important in the cupola as in the blast furnace. Just as long as these factors are allowed to vary as they now do, we can expect wide variation in the qualities of pig iron and of the cast iron made from it.

A combustibility test such as described in the appendix to this paper, a properly conducted rumble test, or both, would suffice to control the quality of the coke. Removal of the moisture from the blast furnace and cupola blasts can be economically produced by an adsorption process. As soon as some pig iron producer is in a position to control these two major causes of

variation and a cupola is equipped with a blast dryer, it will be possible to conduct further experiments to trace the cause of variations which have not as yet been explained.

The inferences and conclusions which can be drawn as a result of this investigation follow.

1. Physical characteristics of pig iron persist through the cupola melting operation and are conferred upon the cast iron to which it is converted.
2. The formation of iron carbide is apparently fostered by the presence of moisture in the blast. The quantity of combined carbon formed increases with increase of water in the blast.
3. Properties of the cast iron which are dependent upon the amount of combined carbon present and upon the ease with which combined carbon is retained by rapid cooling are, therefore related directly to amount of moisture in the blast.
4. Machinability of cast iron improves with diminishing quantities of moisture in the blast.
5. Tendency for the formation of white iron diminishes as the moisture content of the blast is reduced.
6. Tendency for the formation of shrinkage cavities is decreased by increasing the rate at which the ore burden travels through the blast furnace.
7. The rate at which the burden can be made to travel through the blast furnace depends upon the burning rate of the coke used.
8. A cast iron of a given analysis such as T.C.-3.30, Mn-0.50, P-0.15, S-0.085, Si-2.35 poured in dry or green sand, other conditions being constant, will vary in hardness twenty-five to thirty points of Brinell hardness, depending upon the quality of the pig iron used in the charge.
9. In a cast iron of above analysis a variation of silicon from 2.20 to 2.50 per cent silicon, other conditions

being constant, will produce a drop in hardness from five points Brinell to thirty points Brinell, depending upon the quality of pig iron used in the charge.

10. The factors responsible for variations of tensile strength were not revealed by this consideration. It can be said, however, that the tensile strength is influenced to a marked degree by the pig iron.
11. Machinability is improved by use of pig iron which has been completely reduced in the blast furnace and is made more difficult by too rapid progress of iron through the blast furnace.
12. The quality of the coke used in a blast furnace affects the pig iron in several ways making it extremely important to have accurate control of this material.

In the light of information presented in this paper, it would seem that the custom in vogue for some time past of referring to satisfactory and unsatisfactory pig iron as "good" pig iron and "bad" pig iron is not particularly well chosen. We are beginning to suspect that there is an endless variety of pig iron dependent for its character upon the constantly changing conditions of blast furnace operation.

The pig iron which may be satisfactory for one man's needs may be unsatisfactory for another and vice versa. If a foundryman has adapted his melting practice to give him good results with a particular kind of pig iron, he will probably have trouble with other kinds and so be inclined to call the pig iron bad which gives him trouble but a readjustment of his melting practice might give him just as good results with that iron.

The thing every foundryman is interested in, I believe, is to obtain pig iron which always behaves the same. What he wants is uniformity of raw material. To get that it will be necessary to start back at the blast furnace and eliminate some of the tremendous variations we know exist there. When we can maintain constant some of the biggest variables in blast furnace practice and make further study of pig irons we will probably learn

enough about different kinds of pig iron of like chemical analysis to be able to classify them in something like the manner in which steels of like analysis have been subdivided into fine-grained and coarse-grained, fine-grained normal, coarse-grained normal, fine-grained abnormal and so on. Instead of calling pig iron "good" and "bad" we will refer to it for example as No. 2X soft, No. 2X hard, No. 2X non-chilling, No. 2X l.v.s. (for low volume shrinkage) or by some system of classification which will indicate the character which we can expect to be transposed from the pig iron to the cast iron made from it.

In closing, some of the blast furnace data is again presented in order to leave with the reader the picture of what a variable thing blast furnace operation is. This is shown in Table 7.

Table 7

	Limiting Values Observed	
	Maximum	Minimum
1. Coke used per long ton of iron produced.....	2440	1765
2. Pounds of air used per lb. of carbon in coke.....	6.3	4.27
3. Pounds of air used per lb. of iron produced.....	5.45	3.29
4. Pounds iron produced per hr. per sq. ft. area at max. diam.	179	95.8
5. Pounds of water in blast per ton of iron produced.....	121.6	22

It happens that these variations did not all occur in the same furnace but there is no reason why they shouldn't and probably do over a period of time. The extreme values given for coke consumption did occur within a week's time in the same furnace.

Until measures are taken to reduce these fluctuations of factors which have a direct bearing upon the quality of the iron, we can expect to get pig iron of variable quality. There is now available means for controlling two important variables which themselves are the main cause of a large share of the other variables. These two variables are coke quality and amount of water in the blast. Means of controlling these have been discussed in this paper.

Appendix

Combustibility Test for Coke

(Developed by the author in the General Motors Research Laboratories and used by General Motors Divisions for testing coke).

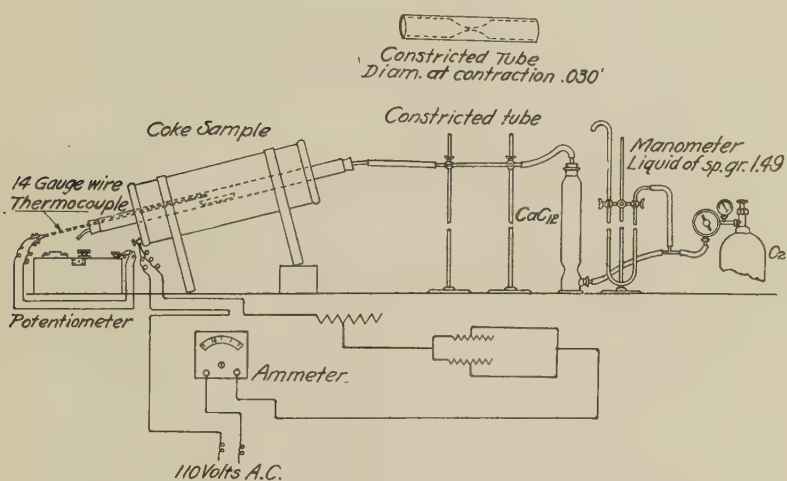


FIG. 22—APPARATUS ARRANGEMENT FOR COKE COMBUSTION

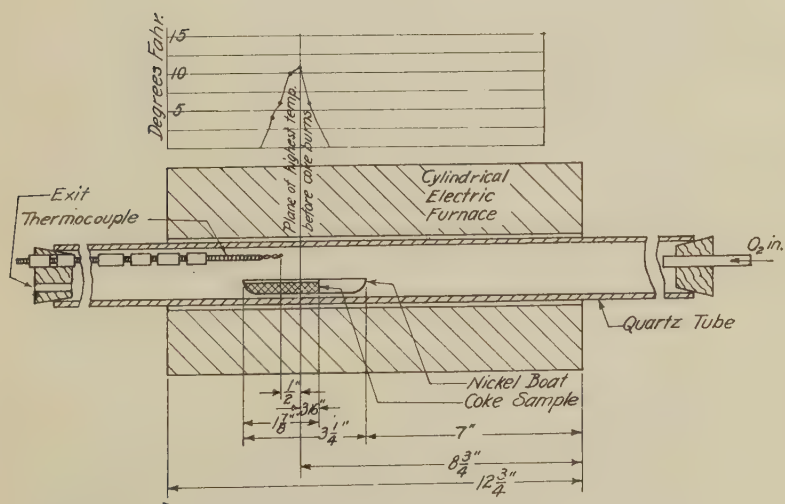


FIG. 23—DETAILS OF COMBUSTABILITY TEST APPARATUS AND ARRANGEMENT

Specifications for Sampling

Method of Sampling

1. Each carload, or its equivalent, should be considered as a unit.
2. The samples should be taken from the exposed surface of the car. Samples shall be selected along three parallel lines—one running down the center of the car and the other two along each side, about one foot from the edge of the car. Lumps of coke shall be selected, at intervals of approximately two feet. When two lumps of coke lying side by side where a sample is to be selected, are apparently very different in quality, both lumps should be selected.
3. The total quantity of sample collected in the above manner, should be not less than 50 pounds.
4. The above 50 pounds sample shall then be reduced in quantity by quartering. The diagonally opposite quarters shall be discarded, thus leaving a sample of 25 pounds. This 25 pounds sample should then be crushed to pass through a 1-inch mesh sieve and then quartered twice, reducing the sample to 6 pounds. This amount is then crushed until the particles will pass through a $\frac{1}{4}$ -inch mesh sieve and be held on a $\frac{1}{8}$ -inch mesh sieve. That which passes the $\frac{1}{8}$ -inch mesh sieve, is discarded and the remainder used for the test. From the sample prepared in this way, 6 one-gram samples are weighed out to be used for the combustibility test.

Combustibility Test Procedure

1. The apparatus required for this test, consists of an ordinary carbon combustion furnace, a thermo-couple coated with a refractory cement; a potentiometer, ammeter, calcium chloride tower, U tube manometer, standard constricted tube and oxygen supply.

2. The apparatus shall be arranged as shown in Fig. 22. The carbon combustion furnace is tipped so that the outlet end of the quartz tube is lower than the boat containing the sample, in order to facilitate the exit of the heavier gaseous products of combustion. The ammeter is placed in series with suitable resistances so that the current passing through the furnace can be accurately controlled.
3. The amount of oxygen passing through the furnace depends on the pressure and the size of orifice in the constricted tube. The bore of this constricted tube is .030 inch. The proper amount of oxygen is obtained by maintaining a manometer pressure equivalent to 22 inches of Brom-Benzene, having a specific gravity of 1.49.
4. It is necessary to calibrate the furnace to determine the location of the hottest part of the furnace. With the oxygen current passing through the furnace at the standard rate mentioned in paragraph 3, a traverse with the thermo-couple is made from one end of the furnace to the other, to determine the location of the hot-spot. The position of this point is important in placing the coke sample in the furnace.
5. The one-gram sample of coke is placed in an ordinary nickel boat, commonly used in carbon determinations. The particles of coke are arranged in such a manner that there is only one layer of particles in the boat. The whole sample is confined to $1\frac{7}{8}$ inches at the end of the boat, away from the oxygen entrance end.
6. The nickel boat containing the sample of coke is placed in the furnace approximately coinciding with the hot-spot in the furnace. The exact position of the boat, relative to the hot-spot in the furnace and the thermo-couple, is shown in Fig. 23. It is very important that this position be exactly maintained in all tests. When the coke sample is inserted in the

furnace, the furnace should be at approximately 750 degrees Fahrenheit. The oxygen current is turned on and the furnace maintained at that temperature for 5 minutes to allow the boat and sample to come to equilibrium. The current, through the furnace heating element, is then adjusted to 2.65 amperes. This current will heat the furnace up at a rate of 7 or 8 degrees per minute, in the neighborhood of 750 degrees Fahrenheit.

Readings of the furnace temperature must be taken every 30 seconds until the coke has completely burnt. The ignition temperature of the coke will be indicated by an abrupt increase in the rate of temperature rise of the furnace. When the coke is completely burnt, the furnace temperature will again fall off.

An Open-Flame Stationary Hearth-Type Furnace for Melting Aluminum and Its Alloys

BY ROBERT J. ANDERSON, D. SC.,¹ GEORGE E. HUGHES,²
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Introduction

This paper describes an open-flame stationary hearth-type furnace suitable for use in melting aluminum and aluminum alloys. The present writers have designed, built, and operated a number of furnaces of this general type in the past ten years, and have found them to be eminently satisfactory. Moreover, the furnace to be described here has application for a number of different melting operations in the aluminum industry. It is well suited for melting in both sand and permanent-mold casting work. The furnace, with variations in design, may be built in capacities of up to 50,000 pounds of aluminum or even larger. Furnaces of this type ranging from 2,000 to 50,000 pounds capacity have been built by the writers.

The question has often been asked: What is the best type of furnace to use for melting aluminum alloys in foundry practice? Various answers have been given to this query, the consensus of

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opinion being that no particular type of furnace is best suited to all possible conditions. However, as indicated just above, the present type of furnace is well adapted for a number of different applications, and where the quantity of metal to be dealt with is sufficiently large, this furnace may be regarded as practically universal. The fuel efficiency of the open-flame furnace and its high melting speed are advantages which are well known.

It should be said in passing that the tendency in aluminum-alloy casting practice of late years has been toward melting in large units. This has become a necessity because of the large production turned out daily by the leading foundries. Too, the size of castings poured has been continually increasing. The technique of handling large quantities of liquid aluminum alloys has now been well developed. In the case of alloys to be poured into castings for heat treatment, it is desirable to make the alloy up first, then pour into pigs, analyze, and then make any desired corrections in the composition on a second melting. Naturally, it is preferable to prepare such alloys in large lots.

In general jobbing work, there has been a marked tendency in the past ten years to use large quantities of casting scrap in the furnace charges. This scrap is of such a character that it must be melted down in a furnace of considerable size, having large doors, or else be broken up for charging into small furnaces. Speaking generally, and taking into account present conditions, it appears to the writers that the hearth-type furnace is one of the best all-around furnaces to use where the amount of metal to be handled daily is sufficiently large.

Melting Furnaces in General

In a discussion of furnaces for melting aluminum and its alloys, it has been pointed out by one⁴ of the writers that a great variety of furnaces are used and that there is no standard practice. Thus, in foundry work, the following types of furnaces are, or have been, employed: Gas- or oil-fired stationary or

⁴Anderson, R. J., *Aluminum and Aluminum-Alloy Melting Furnaces*, Trans. American Foundrymen's Association, Vol. 30, pp. 562-604, 1923.

tilting iron-pot furnaces; gas- or oil-fired stationary or tilting crucible furnaces; coke-fired pit crucible furnaces; gas- or oil-fired open-flame tilting pear-shaped (so-called "tea kettle") or cylindrically-shaped furnaces; gas- or oil-fired open-flame stationary hearth-type (so-called reverberatory) furnaces; gas- or oil-fired open-flame tilting reverberatory furnaces (usually of small capacity), and electric furnaces, principally of the resistor type.

In secondary aluminum work, iron-pot furnaces, crucible furnaces, and open-flame stationary hearth-type furnaces have been used largely; the firing is usually by oil and less often by gas. In rolling-mill practice, the open-flame stationary hearth-type furnace is favored, although other types have been employed. The hearth-type furnace in rolling-mill work is fired by gas, oil, coal, or coke. Some operators prefer coke firing. Some other types of furnaces not mentioned above have been used in a small way in the aluminum industry.

Speaking generally, in foundry practice, aluminum alloys have been melted in relatively small quantities. Thus, typical furnaces which have been favored for foundry melting include the stationary iron pot of 300 pounds capacity and the tilting iron pot of 500 pounds capacity. On the other hand, in some plants, open-flame cylindrical furnaces of 1,000 pounds capacity, and stationary hearth-type furnaces of about 6,000 pounds capacity have been used to a less extent. Small units are uneconomical to operate, both as to labor and fuel, when the total quantity of metal to be handled per day is large. Moreover, a battery of small units having capacity equivalent to that of a single large unit takes up an undue amount of floor space.

Where daily output is small, say upwards of one to three tons, the small iron-pot furnace is satisfactory, although even when handling such relatively small quantities, the present writers prefer an open-flame furnace. The open-flame stationary hearth-type furnace may be built in any reasonable size to suit requirements. While the iron-pot furnace has been generally favored in foundry practice, and in fact has been fairly standard (if any furnace in aluminum-alloy foundry work has been standard),

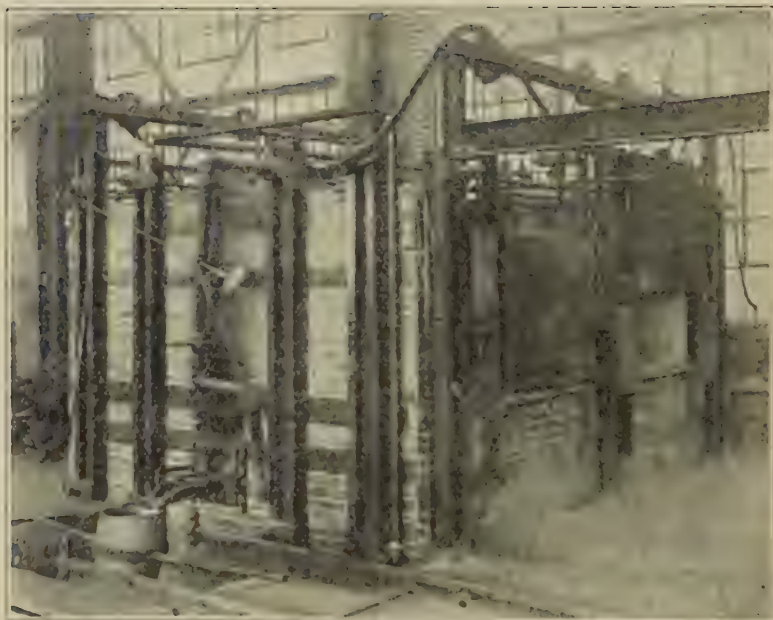


FIG. 1—PHOTOGRAPH OF 12,000-POUND CAPACITY OPEN-FLAME
STATIONARY HEARTH-TYPE FURNACE, AS BUILT

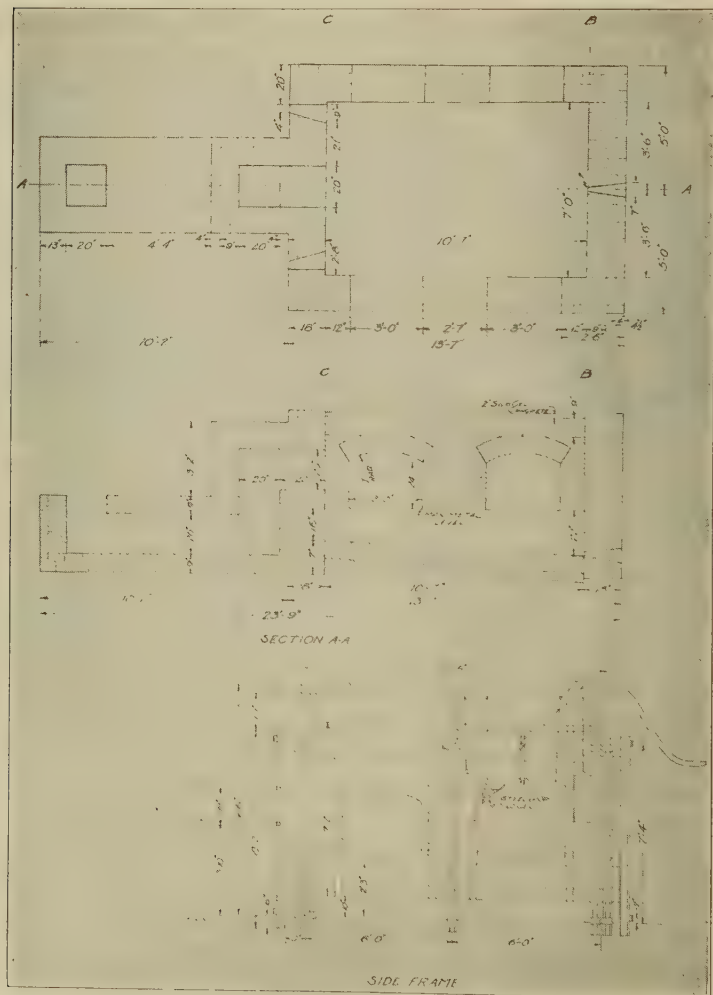
the writers feel that the hearth-type furnace is far superior, particularly as regards fuel economy.

Description of the Hearth-Type Furnace

Fig. 1 shows a photograph of a 12,000 pound capacity gas-fired open-flame stationary hearth-type furnace as built, and Fig. 2 is a detail drawing showing the construction of the furnace. The figures are self-explanatory. The hearth, side walls, and roof are built of good grade fire brick, while the outside face walls may be made of common brick. Preferably, a 4-inch layer of insulating material such as cork brick or sil-o-cel brick should be run between the 9-inch wall, hearth, and roof bricks and the outside facing bricks. Light old rails may be used for the buckstays. Furnaces of this type must be well ironed in order to counteract the expansion of the walls when heated. Casing with steel or cast-iron plates is not necessary with the smaller furnaces, but is advisable in the larger sizes, at least to cover the walls from the upper limit of the metal level to a few inches below the floor line. In the smaller sizes, e. g., 2,000 pounds' capacity, the entire furnace, except the roof, may be cased, and buckstays not used. A good solid foundation should be provided for this type of furnace.

In the preferred design, cross firing is employed, i. e., the burners are situated in the back wall (at the stack end), and the products of combustion must pass outward from the burners towards the front wall and then back to escape through a flue to the stack. This method of firing has shown definite economies over firing through the side walls or the front wall. For further fuel economy, it is advisable to keep the furnace fairly well heated even if not in use for melting for reasonably short periods of time, e. g., a few days. This practice will, incidentally, increase the life of the refractories. The furnace may be fired by gas or oil as desired. In the design shown, the flue was built as indicated in order to locate the stack outside of a building. In usual construction, the stack would be built against the back wall, and the burners would be situated on either side of the stack.

As will be seen, the furnace has four large charging doors, two on either side. These doors permit easy and rapid charging. Liquid metal is removed from the furnace by tapping through a tap hole and runner in the front wall. Small or large quantities of metal may be readily removed from the furnace into carrying



IN FIG. 1

FIG. 2—DETAIL DRAWING SHOWING CONSTRUCTION OF THE FURNACE

crucibles or bull ladles. In tapping, metal is permitted to flow down the runner by simply pulling out the tap plug and inserting a "needle" bar into the tap hole to break through any incrustation. When sufficient metal has been taken out, the flow is stopped by inserting another plug. Melting is rapid, and dross losses are reasonably low with proper burner operation. In the furnace shown, the melting time is about three hours for 10,000 pounds of metal, if cold metal is charged to the furnace heated to 1,400 degrees Fahr.

The furnace may be fired with the usual conventional burners, details of which need not be given here. The life of the open-flame hearth furnace, if properly constructed and "broken-in" and given adequate attention, is at least two years. If run steadily, the walls should be chipped down about once a week. Any cracks which occur in the walls, hearth, roof, or around the doors should be promptly repaired.

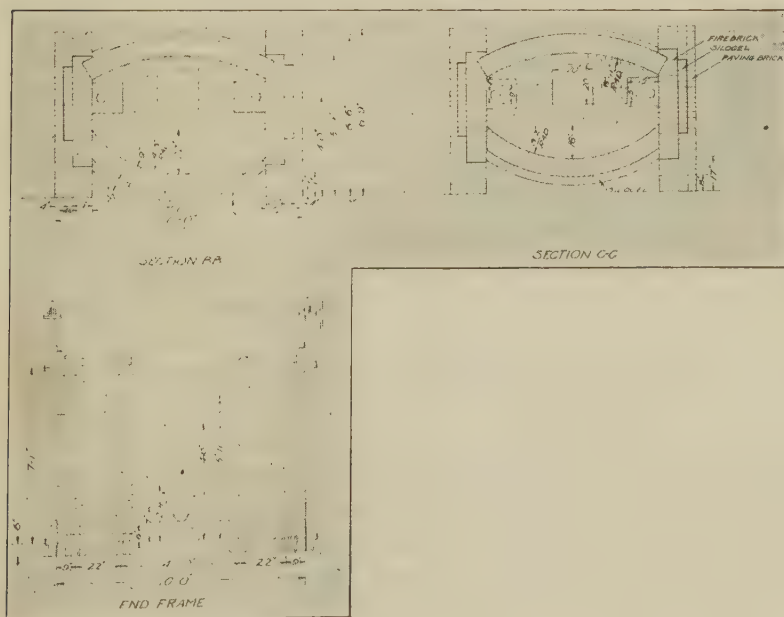


FIG. 3—END FRAME AND SECTIONS B-B AND C-C OF FIG. 2

Application in Melting Different Materials

As already stated, the furnace under discussion has application for a number of different melting operations in aluminum work. Thus, in sand-foundry practice, alloy ingot of suitable composition as furnished by secondary smelters or other producers, for making castings, may be simply charged together with gates, risers, and other foundry returns, and melted. The melt may readily be maintained at the proper temperature, and metal removed as required for pouring. In the same way, casting alloys may be made up in the furnace from a suitable charge of primary metal, scrap, and hardeners. In permanent-mold-casting practice, after charging and melting, the liquid alloy may be drawn off and distributed to holding pots as required. In alloy casting work, the 10,000- to 25,000-pound capacity furnace has the advantage of providing large quantities of metal of the same analysis, as contrasted with a battery of small units where the metal from each unit is liable to vary in composition. Of course, in melting large quantities of alloys, the bath should be stirred frequently and at least before any tapping so as to avoid segregation.

In secondary aluminum practice, the furnace is well adapted to melting all kinds of scrap. Thus, large and heavy scrap, like old crankcases, can be readily charged, the doors being sufficiently wide to take such scrap without breaking it. Too, the puddling of borings or dross metallics may be readily done in this type of furnace. The larger sizes are especially suitable for use in secondary aluminum work, since it is advisable to remelt scrap in large individual lots. Hardeners, for use in making fixed additions of alloying metals to aluminum, can be readily made in the open-flame stationary hearth furnace, unless of too high melting point. Thus, 50:50 copper-aluminum and 90:10 aluminum manganese may be made to advantage in this type of furnace. For hardeners of rather high melting points, the writers prefer the open-flame cylindrical tilting furnace, but not of large capacity.

Finally, this furnace is quite suitable for melting aluminum

and its light alloys for the production of rolling ingots and other ingots, billets, and shapes for subsequent working.

In the writers' practice, the furnace in question has been used for all the purposes above mentioned.

Fuel Efficiency and Cost of Melting

As is well known, aluminum and aluminum-alloy melting furnaces have been notoriously inefficient as to fuel consumption per unit weight of metal melted. Thus, the ordinary stationary or tilting iron-pot furnace has a fuel efficiency of only 6 to 10 per cent, using either gas or oil as the fuel, while the average efficiency of the open-flame pear-shaped furnace is about 15 per cent. Tests on several different units of the present type of furnace show fuel efficiencies of 20 to 25 per cent.

Thus, taking a given furnace of the general design shown but having a capacity of 26,000 pounds and having two opposed burners in each side wall, and using figures obtained during a run of about one month on heavy melting stock, it was shown that the gas consumption was about 2 cubic feet per pound of metal melted. The fuel was natural gas, having a calorific value of about 1,000 B.t.u. per cubic foot. As may be shown by simple calculation, it requires about 495 B.t.u. to raise one pound of aluminum from room temperature to 1,400 degrees Fahr. With 1,000 B.t.u. gas, there is actually being used about 2,000 B.t.u. to accomplish the melting. Hence, the indicated furnace efficiency is

$$\frac{495}{2,000} \times 100 = 24.75 \text{ per cent}$$

In this case, the gas consumed included that required for pre-heating the furnace, maintaining it hot between charges, melting, and holding the metal at the required temperature. Figuring gas at 37 cents per 1,000 cubic feet, or 1,000,000 B.t.u. for 37 cents, then the cost of the fuel for melting is 0.074 cent per pound or \$1.48 per short ton.

Preliminary figures obtained during the course of tests on

furnaces fired from burners in the end wall at either side of the stack indicate higher fuel efficiency by this method of firing. Of course, it is understood that the indicated efficiency of any metal melting furnace is affected by many factors, and a given furnace may show widely different fuel consumption under different conditions.

Some Factors in the Production of Sound Gray Iron Castings

BY R. W. KURTZ,* NEWCOMERSTOWN, O., WITH INTRODUCTION

BY KENT S. CLOW,† CHICAGO

INTRODUCTION

There is a great demand for better gray iron castings. The chemical and research engineers have given to the foundrymen the fundamentals that were lacking a few years ago, upon which can be built an organization that will produce more consistently sound castings than ever before in the history of this industry. Why does not every gray iron foundry employ these fundamentals?

There are several apparently sound reasons, all of which our own experience has proven wrong. The first is that the average foundryman doesn't personally understand all of the rather complicated papers—the engineering equations and the confusing graphs that the research men present from year to year. It looks like a lot of nonsense to go through to determine whether sand is in proper condition for his work and for the smaller foundry it looks as if it were too expensive. He has been unable to see how such tests were going to make better castings and for many it has been hard to see how it was going to make more money.

Our own experience over the past ten years has perhaps

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Discussion of this paper begins on page 566.

been an example which will prove to the average foundryman that for the good of the industry, for the future of his business, and for the good of his pocketbook, he should get someone into his foundry to put into practice the available tests on all materials used and establish standards for his own work that will improve the quality and reduce the cost and above all else, remove the guess from the foundry industry.

Ten years ago, we relied upon the foreman to feel his sand—we had a chemist who analyzed our iron—but we stopped there. If we had bad castings we blamed the foreman or the workman. Many castings that looked good on the outside probably were not as sound throughout as they should have been and hidden defects in castings have done more than anything else to hurt the industry.

Our start towards the establishment of standards was modest, and yet we had to practically blaze our own way, where today data are available for any foundryman to follow that will make the work simple in comparison. The writer of this paper, just out of Ohio State University, under the guidance of our manager, started to find the right kind of sands for molds and cores—to study all of the causes for losses of defects in castings and to work out with the practical assistance of the shop foremen, the selection of proper materials, and later the best methods of melting and pouring and the design of good equipment.

This paper describes some of the tests and principles employed in our present practice. It may seem to some to involve unwarranted complication and expense. It does neither. In the average foundry one technically trained man can easily handle the necessary test and special development work. Data are available that will immediately solve most of your problems and the saving in cost and above all the improvement in the quality of product will repay the expense many times.

Nothing would improve the reputation of gray iron castings more than the universal use of the accumulated knowledge on sand, iron, and pouring methods, and nothing would remove the guess from the industry and save the individual foundryman more worry and money. From our own experience we know this to be a fact. From our own experience we know that the

initial step is the hardest—the development of the work once it is properly started will be simple and the results far reaching.

TECHNICAL CONSIDERATIONS

The most fundamental requirement for the production of quality casting is an engineering staff intimately familiar with foundry problems. In fact, this is so fundamental that it is apt to be overlooked or at least obscured in importance by the more evident and spectacular results, mistakenly credited to operating departments.

Engineering is the most fundamental of the applied sciences. It is the pilot of industry—of our own, the foundry industry. We hold that almost everyone prefers to do a task rightly if it may be done so, easily. Therefore the *primary* responsibility for both good and defective castings may be said to rest with the engineering departments. We all know how much simpler the secondary and supervisory responsibilities become when the tools and equipment have been skillfully designed.

Complex problems are only combinations of simple ones which yield to the application of a comparatively few fundamental principles. The efficient solution of an engineering problem consists first, in the development of the simplest possible layout, consistent with the accomplishment of the desired result; second, in the choice of materials of construction, most economically suited to the layout; and third, in the selection of details most favorable to construction with these materials.

The third step is by no means the least important. On these details hinge many possible economies, and sometimes the success of the whole venture. The proper design of a casting requires a great deal of study and specialized ability.

To enumerate every possible factor of design involved in the accurate production of castings would be beyond the scope of this paper and the ability of its author. An attempt is made, however, to briefly outline the four principal considerations which enter into an efficient casting design:

1. Economical distribution of metal to secure necessary strength with minimum weight. Cast metals are most efficient in compression.
2. Uniform distribution of metal to avoid cooling strains and shrinkage cavities. This means the careful proportionment of each rib, fillet, boss, flange, lug, etc.
3. Simplification of molding operations. This is achieved by the allowance of ample draft, by use of straight parting lines, and by anticipating means for the proper holding and venting of cores, when the use of cores is necessary. In the case of very complicated or large unwieldy designs, it is sometimes advisable to simplify the molding by casting certain members separately, especially parts subject to wear or breakage.
4. Simplification or elimination of machining operations. This is accomplished by the use of cored holes, cast inserts, or chilled surfaces. Also by the provision of ample clearances and the allowance of minimum finish.

Molding Materials

To intelligently develop proper tools and methods for quantity production in sand molds, a great deal of information about sand is required.

Comparatively recent research work has enabled foundrymen to test and control their molding sands with a greater degree of accuracy than was possible, or even considered necessary, in the past.

The sand tests which are regularly employed at our foundries are as follows:

1. *A. F. A. Sieve Analysis.*
This analysis is valuable for estimating texture, particularly of new sands and facings.
2. *Fusion Cone Number.*
This value is useful in estimating the refractoriness of core sands, facing sands and daubing clays.
3. *Strength.*
All of our molding materials are tested in tension.
4. *Moisture.*
Percentage by weight is determined at 110 degrees Cent.
5. *Permeability.*
Permeability by A. F. A. machine, tensile strength and moisture tests are made daily or oftener in control work. Lower limits only are set on permeability and strength, but both upper and lower limits are set on moisture.

For the test values to have a practical meaning, the methods of determination must be reliable and the influence of mutually related variables must be thoroughly understood.

As a result of our sand test work we offer the following general statements:

1. A rough relationship exists between the tensile, shear, and compressive strengths of practically all rounded-grain sand mixtures, green or dried, and with or without organic binders. Our results indicate the shear strength to run from 1.5 to 2.5 and the compressive strength from 8 to 15 times the tensile strength.

2. Tensile and shear tests share an advantage over compression and transverse tests in that the former may be conveniently used for the full range of materials, molds to cores. This greatly simplifies testing and permits true comparisons between mold and core strengths, which would hardly be possible with molding sand tested in compression and baked core mixtures broken by tensile or transverse loading.

3. The strength should, if possible, be determined on the same specimen used for permeability. Appendix "A" describes a method which we developed for tensile determinations after we had experienced difficulty in getting consistent results with methods which break the specimen across a section perpendicular to the direction of ramming.

4. A ball hardness test is valuable for determining and interpreting the properties of actual molds and cores. This may be accomplished with a fair amount of accuracy by testing the strength and permeability of samples which have been rammed just enough to give hardness values corresponding to those found in actual practice.

5. The strength or cohesiveness is dependent on six variables:

- a. *Amount of free moisture.*

The maximum green and dry strength of any sand mixture is developed by widely different moisture

¹*Strength Tests of Foundry Sands*—Adams, T. C., Trans. American Foundrymen's Association, Vol. 34, p. 486.

contents. The moisture which develops maximum green strength is usually slightly less than that for maximum permeability and for that which gives the best tempered working condition. A typical relationship is shown by curves, Fig. 1. The proper moisture for any sand varies almost directly as the clay content.

b. *Amount and kind of bond.*

Up to 20 per cent clay substance, the maximum green and dry tensile strengths of straight sand-clay mixtures vary directly as the amount of the particular clay substance used. Clay substance improves the strength of all mixtures except those containing binders, such as core oils, which are absorbed and rendered ineffective by traces of clay and silt.

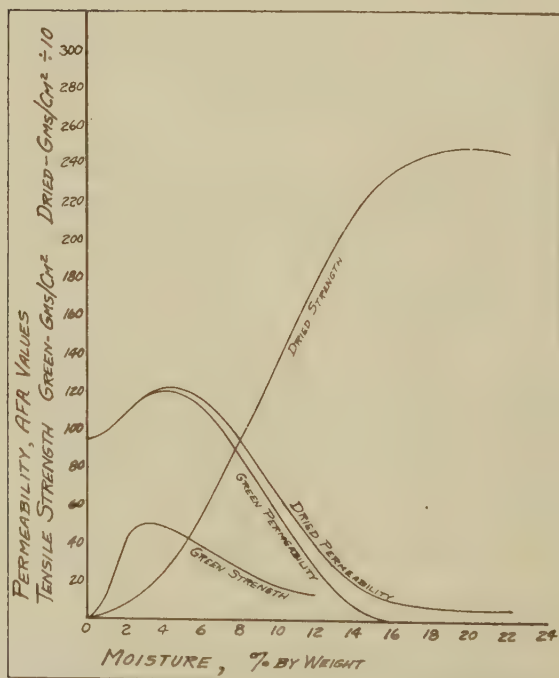


FIG. 1.—EFFECT OF MOISTURE ON STRENGTH AND PERMEABILITY OF A TYPICAL MOLDING SAND

c. *Size and character of sand grains.*

In general, the smaller or more non-uniform the sand particles, the greater will be the green and dry strength.

d. *Intensity of mixing.*

The more intimately the material is mixed, the more strength will be developed. The proper mixing of sands with plastic substances like clays, requires a rubbing rather than a tumbling action, in order that the clay may coat the grains instead of merely fill the void spaces.

e. *Intensity of ramming.*

The curves of Fig. 2 show how the strength and permeability of a green molding sand are influenced by the ramming work per unit volume of specimen.

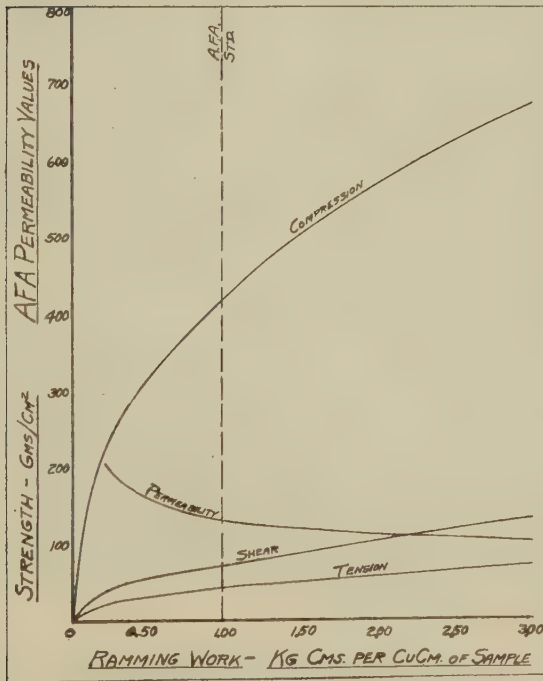


FIG. 2—EFFECT OF RAMMING ON GREEN STRENGTH AND PERMEABILITY OF A TYPICAL MOLDING SAND

f. *Drying temperature, if dried.*

In general, long periods of slow drying give higher and more consistent strength values, then short periods at high temperatures.

6. The maximum green to maximum dry strength ratios vary widely for different clays. Values have been found from 1:30 to 1:200.

7. Permeability values determined on uniform sizes of round sand grains vary directly as the square of the grain diameters. The permeability of any sand cannot be greatly different than that of the finer 30 per cent which fills the void spaces of the coarser portion.

8. The permeability of a sand-clay mixture of any moisture content is not greatly improved by drying. Microscopic examination shows that when very wet mixtures, such as loams, are dried, the clay particles are deposited in a manner tending to produce an *unconnected* system of void spaces, in place of a connected system, which is essential for free gas passage. Of course very little permeability is required when the free moisture has been completely removed by drying and the net result is a greatly decreased possibility of blow holes.

9. Sufficient plasticity for loam sand work is developed with about 15 per cent moisture and 15 per cent clay substance. Drying cracks begin to develop when the clay substance exceeds 25 per cent, especially in connection with excessive moisture or high oven temperature.

10. Cohesive value and cleaning properties of dry and wet surfacers, or facings, may best be determined (so far as we know at this time) by pouring a deep, open, test mold. It is very important that facings do not scab off and become entrained in the metal. The solid inclusions themselves are often not as harmful as the internal gas pockets which are caused by volatiles in the mixture. See A of Fig 3.

11. The "blowability value" of a sand may be defined as the gas pressure, measured in grams per square centimeter, generated when molten iron at 2450 to 2500 degrees Fahr. is poured

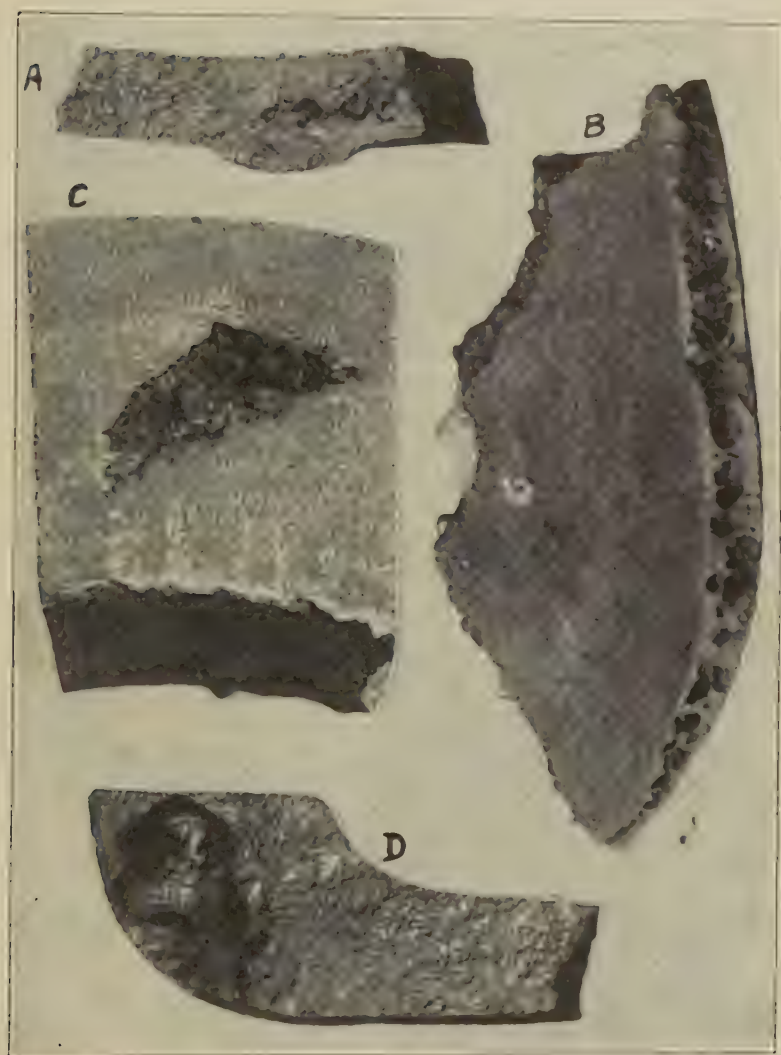


FIG. 3—THE FOUR CLASSES OF DEFECTS DISCUSSED: A, SCAB INCLUSIONS; B, MOLD OR CORE GAS HOLES; C, LIQUID SHRINKAGE; D, IRON OXIDE REACTION.

on the standard permeability specimen. Appendix "B" describes the device which we use to measure this pressure.

The pressure is a function of the volatile matter and permeability of the sample and may be calculated approximately from the expression:

$$\frac{K_w W}{P(1 - CW)} \quad (1)$$

where P represents the permeability, W, the weight of volatile-bearing-substance (v. b. s.) in the specimen, K_w , a constant which depends on the rate of formation and density of the gases generated, and C, a variable which expresses the effect of the condensate that collects in the cooler portion of the specimen and thus reduces the original permeability.

The value of C ranges from practically zero for dried or very coarse, open sands to 0.06 for very fine or compact moist sands. For rough estimating purposes C may be taken at an average value of 0.04 when dealing with free moisture, and as zero for dried specimens. Experimentally determined values of K_w for several common substances are given in the Table 1.

Substituting these values the general expression (1) becomes, for free moisture:

$$\frac{60W}{P(1 - 0.04W)} \quad (2)$$

where W = total grams used for specimen times per cent moisture, and P is the AFA permeability value of specimen.

Table 1

TABLE SHOWING RELATIVE GAS PRESSURE VALUES FOR VARIOUS MOLDING MATERIALS

Substance	Sp. Gv. (as used)	K_w (by weight)	K_v (by volume)
Free Moisture	1.00	60	..
Combined Moisture	..	10	..
* Seacoal	0.84	5.5	4.5
* Wheat Flour	0.46	10.5	5
* Corn Starch	0.62	11	7
* Dextrin	0.52	14	7
* Molasses	1.30	4	5
* Glutrin	1.25	5.5	7
* Glue	1.07	3	3
* Linseed Oil	0.93	6	5.5
* Pulv. Rosin	0.62	6.5	4
* Pulv. Pitch	0.54	4	2

*Combustible substances have a flash pressure which precedes and is from three to six times as high as the pressure which follows and which is given by the values of above table.

The total weight of a specimen usually amounts to from 150 to 190 grams. If we assume an average value of 170 grams, expression (2) may be written, approximately:

$$\frac{100M}{P(1 - 0.07M)} \quad (2a)$$

where M is the per cent moisture by weight. See curves of Fig. 4.

The interesting part in the expression is the denominator. In practical parlance this term means that due to the accumulation of condensed moisture in the cooler portion of the mold, the initial permeability is reduced at the rate of some 4 per cent for each gram of moisture in the specimen, or, roughly, 7 per cent for each per cent moisture by weight. Thus in green sand work it is very important to use the vent rod freely and to pour rap-

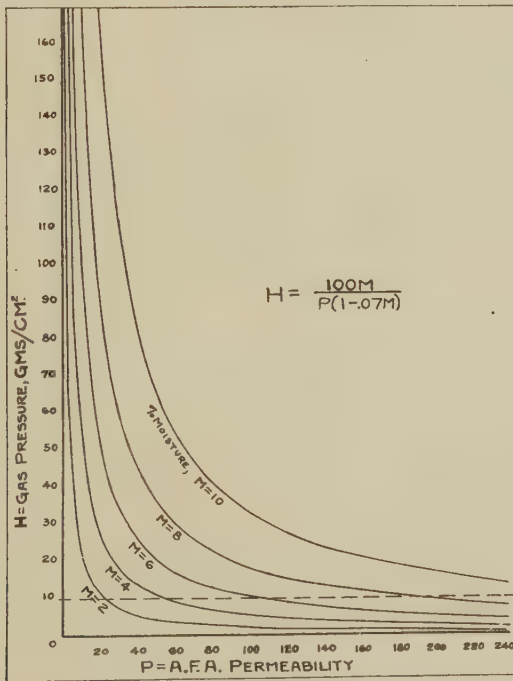


FIG. 4—HYPOTHETICAL EFFECT OF VARIOUS COMBINATIONS OF MOISTURE AND PERMEABILITY UPON MOLD GAS PRESSURES

idly so that the ferrostatic pressure may be developed at a greater rate than the mold gas pressure. On the other hand, it is of no great value to have an excessive vent area on the surface of a flask because the mold gas which actually escapes through the vent holes ordinarily represents such a decreased portion of that generated near the face of the mold that relatively little final exit area is required.

In the case of dry sand molds or cores, the amount of volatile-bearing-substance (clay, seacoal, flour, oil, etc.) is often known in per cent by volume and the general expression (1) may be more conveniently written,

for dried specimens:

$$\frac{K_v V}{P} \quad (3)$$

Where $K_v = K_w$ times specific gravity,

$$\text{and } V = \frac{\text{Total grams used for specimen}}{\text{Grams mixture per cc v.b.s.}}$$

Due to the relatively very low values of K , dried molds and cores never give trouble from "blowing" except when the vent passage is completely closed off or when the drying is imperfect. But if the cope is cut away enough to observe the action of the metal, some blubbering or "kicking" will be found in a large percentage of green sand molds.

Mold gases consist mostly of water-gas ($2H_2 + O_2$). If forced into the metal, the free oxygen, which constitutes about one-third of its volume, will attack the metal vigorously. As a result one is apt to find particles of dross or slag in badly blown castings, and the molder will likely take refuge in the good old alibi "dirty iron."

Blowability values above 10 grams (a little over one-half inch of ferrostatic pressure) are considered dangerous or at least not foolproof at our foundries. Above this value there is a constantly increasing tendency toward scabby surfaces and toward gas pockets, due to the trapping of the primary mold gases or to the secondary oxide reaction which is described in detail later.

Melting and Pouring

The utmost care and precaution exercised in the making of molds and cores may still fail to prevent the occurrence of gas pockets, especially under the cope surface of large or deep castings. These defects are of metallurgical origin and have been variously attributed to the following general causes:

1. Liquid "shrinkage" (outward) in opposition to solid "contraction" (inward).
2. Carbon monoxide gas formed by the reaction of carbon with entrained particles of iron oxide.
3. Sulphur dioxide gas formed by oxidation of manganese sulphide.
4. Liberation at lower temperatures of gases dissolved by metal at high temperatures.

We have never been able to identify either of the last two causes with defects found in gray iron of usual composition range.

Neither have we been able to positively identify the first two causes, which are quite common, with our melting practice. Defective grain structures which tend to porosity, checking, brittleness, etc., have often been traced to melting practice, but actual "blow holes" have invariably been found to originate in certain phases of our pouring or molding practice.

Whenever red hot or molten iron is exposed to contact with air, whether it be in the cupola, ladle, runner, or mold itself, the surface of the metal quickly oxidizes, i. e., combines with the oxygen of the air into compounds called slags, or *oxides*. Unfortunately, for foundrymen, iron oxide can react with any carbon present to form carbon monoxide gas. Both these reactions may frequently be observed in a waiting ladle of iron—the oxides or slag forming on the exposed top surface and the carbon monoxide bubbling up around the sides of the ladle where adhering oxides are being reduced by the carbon of the molten metal.

Unlike oxides formed during the pouring operation, oxides formed during the melting operation have a much greater opportunity to rise, or to be completely reduced while the metal is

sufficiently fluid for the gases formed to escape. Good melting practice should therefore be supplemented by still better pouring practice.

Shrinkage cavities may generally be distinguished by their irregular shape, sometimes described as "pine tree" structure. Carbon monoxide blow holes, however, are not easily distinguished from mold and core blows. Their identity is usually established by systematic elimination of other causes. The diagnosis may then be confirmed by intentional production of the defect in question.

Some general factors which have proven helpful in avoiding these metallurgical defects are mentioned below:

1. Temperature of metal should just be sufficient to "run" the casting and generously proportioned gates should be used for this purpose. Excessive temperatures mean excessive liquid shrinkage and often cavities from strained mold sections. The proper pouring temperature depends upon the composition of the metal and the size of the casting. No satisfactory rule covering the universal case has ever been formulated for pouring temperatures and gating. Individual cases must be handled largely by practical experience and trial.

2. When heavy and light sections cannot be avoided in a design, large risers may be used to "feed up" the heavy sections of the castings. Pumping the metal of the riser with a rod is also helpful. In special cases it is desirable to have the riser or feeders made as part of the pattern.

3. Chills may also be used to expedite the solidification of the heavy sections. Both internal (e. g., large headed nails) and external types are used with varying degrees of success. Different rates of cooling are obtained with external chills by changing their size and their distance from the surface of the mold.

4. *Prevention of iron oxide formation* would, if practical, be the most logical method of avoiding oxide inclusions. For this purpose the atmosphere in a mold being poured should be reducing. The lip of the pouring ladle should actually enter the pouring basin so that the metal will be exposed to the air, the

least possible amount. The surface of the metal in the ladle should be skimmed clean, and may then be covered with blacking, sand, or other protection from oxidation. The sides and bottom of the ladle should be kept as free as possible from oxide incrustations. If oxide inclusions in the ladle metal are suspected, additions of deoxidizing alloys should be tried. It is also advisable to melt sufficiently hot so that the metal need not be poured until tramp impurities have had a chance to rise to the surface.

5. When iron oxide is formed, it can sometimes be prevented from entering the mold. Teapot and bottom-pour ladles are helpful but neither prevents oxides which form in the pouring stream, basin, and mold, from getting into the casting. Skim and strainer gates are moderately successful in that any large foreign particles will be trapped out. A very good idea of the efficiency of any particular style of gate may be obtained by mak-

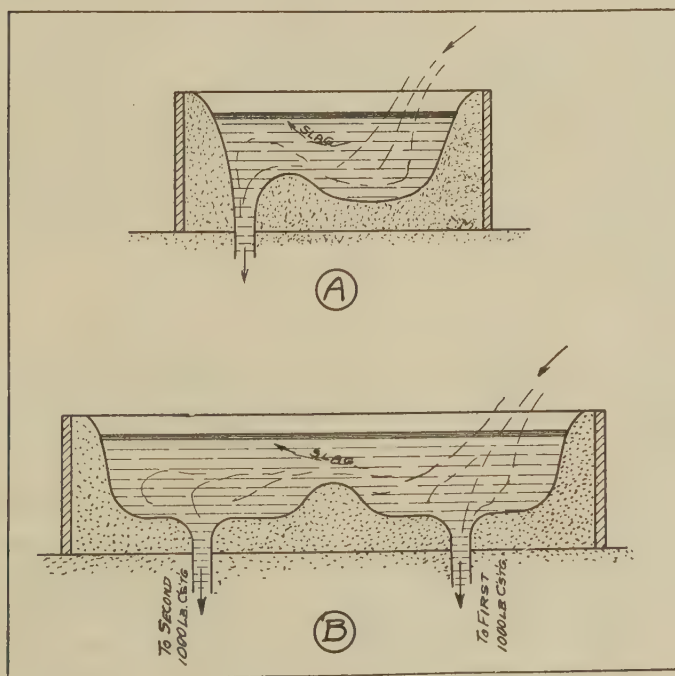


FIG. 5

ing up a model and trying with water covered with ground cork, to represent oxides. The most efficient type we have found is that of A of Fig. 5. The principle of this type is to retard the stream of metal as it enters the mold and thus give impurities a brief chance to rise and be retained in the pouring basin. A very convincing test was made at one of our foundries to compare this type of gate with the direct type. See B of Fig. 5.

Of an accumulated total of 91 castings showing oxide defects, 74 were with direct gating.

6. If oxide inclusions do enter a mold, there are a few remedies possible. (1) The oxide slags may be skimmed from open sand work. The casting should then be covered to about one inch in depth with sharp sand and some dry blacking, which will effectually prevent pitting. (2) The oxide may sometimes be dissolved by additions of borax *to the molds*. (3) In the case of heavy castings, the oxides may be collected in extension heads which are later cut off. When comparing the merits of castings made with and without extension heads, it should always be remembered that to cut off the evidence of trouble is no assurance that all harm has been corrected, especially in the case of small or light weight castings, which solidify too quickly to permit impurities to rise freely. On the other hand, a sound top or cope produced without an extension head, is an indication of sound metal throughout.

Summary

The important points, if any, to which this paper ascribes particular value in the production of sound castings are three in number:

1. *Design* to simplify foundry practice as much as possible.
2. *Test* molding materials and arrange control methods, especially for the moisture in green sand molds.
3. *Pour* at proper temperature and in such a manner that iron oxide particles may not become entrained in the casting.

Appendix A

COMBINATION PERMEABILITY—TENSILE TEST

The special equipment used for this test is shown in Figs. 6 and 7. The only difference between the permeability cylinder of Fig. 6 and the standard AFA cylinder is that the area of the specimen (3.1416 Sq. In.) has been changed in *shape*. The cylinder is filled, rammed and permeability determined in the same manner as with standard cylinder. Values obtained by either, check very closely.

The cylinder is next placed in the tensile device guide, from where the specimen is pushed into the pulling jaws. For loading we use a special Wadsworth core testing machine which is arranged with 1 : 2 leverage for weak specimens and 3 : 1 for strong

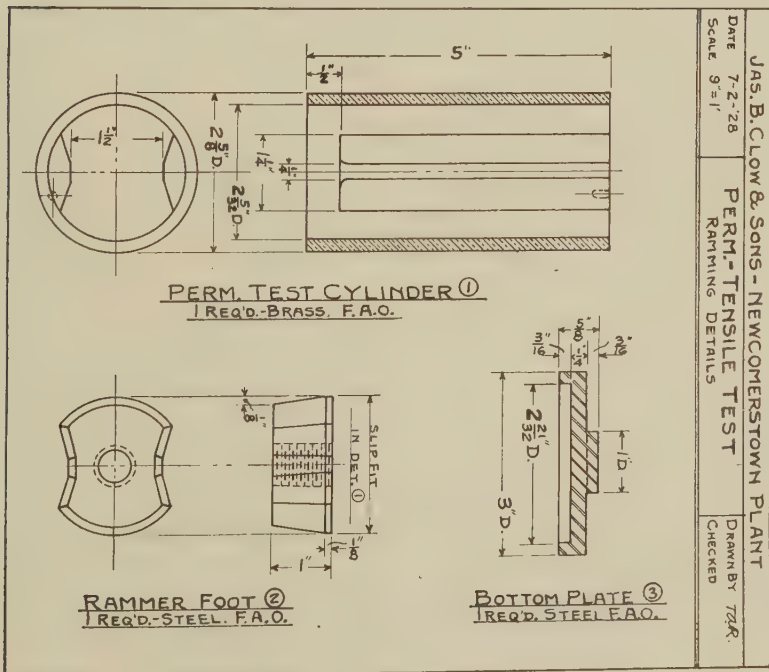


FIG. 6—DETAILS OF PERMEABILITY—TENSILE TEST SPECIMEN AND CONTAINER PARTS

This test has the advantage of speed and accuracy combined with easy manipulation and may be used for both green and dried specimens. Dried specimens can be placed in the pulling jaws better if a slight clearance is provided. Very strong materials can be used in half proportions, if desired, by using half the standard ramming work and half the permeability value obtained.

Appendix B

THE "BLOWABILITY" TEST

The special equipment used for this test is shown in Fig. 8. The test cylinder is first inverted over the ramming stool and

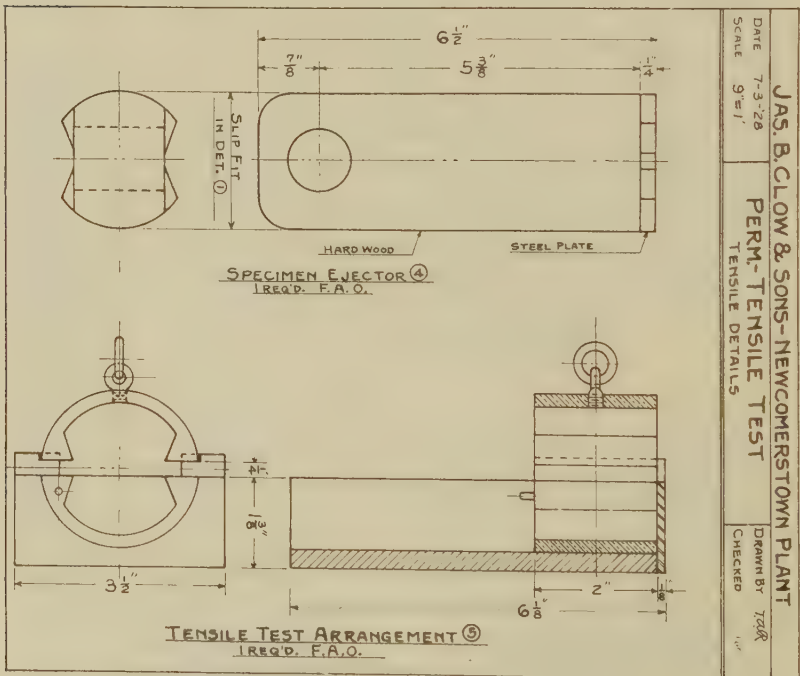


FIG. 7—TENSILE TEST ARRANGEMENT

filled with the proper amount of sand for a 2 inch permeability specimen. After the first ramming blow, with the weight resting on the specimen, a $\frac{3}{32}$ inch diameter needle is run well into the sand through the small tube in the side of the cylinder. After the final ramming blow, the needle is withdrawn and the permeability of the specimen is measured in the usual manner. If the specimen is to be dried, the permeability is measured after drying. In either case the cylinder should be warm enough to prevent moisture condensation prior to pouring.

The small tube on the side of the cylinder is next connected with a manometer by using a short section of rubber tubing wrapped with a wet rag as a protection from the heat of pouring. The cylinder extension is used if the pressure is likely to be high

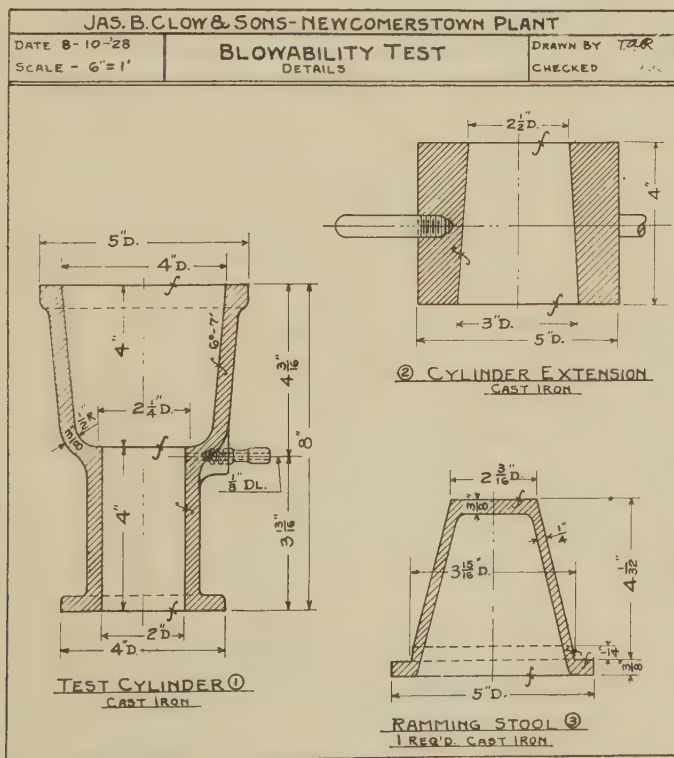


FIG. 8—DETAILS OF APPARATUS FOR "BLOWABILITY" TEST

and the whole poured up as rapidly as possible with iron at 2450 to 2500 degrees Fahr. from a hand ladle.

At the end of about 45 seconds, the pressure indicated by the manometer will have reached a maximum or will be changing very slowly. This value is noted and the cylinder dumped out as quickly thereafter as possible. A pair of circular jawed tongs is convenient for this latter purpose.

With a little care values may easily be obtained which do not vary more than 10 per cent from their average. This test is useful in determining the effect of various combinations of moisture or other volatiles and permeability. It may also be extended to investigations with various pouring temperatures such as obtain with brass, aluminum, etc.

Some Experiences in Sand Control

BY E. F. WILSON,* LOCKPORT, N. Y.

The following report includes a series of observations and studies made in the course of the installation of a sand laboratory and its development to give practical and useful information. The work was performed for the Jefferson Union Company of Lockport, N. Y., which is engaged in the manufacture of malleable iron fittings.

The nature of this paper is chiefly conclusions derived from so many sources of evidence as to render the submission of data impractical. It is hoped that the validity of the conclusions will be further verified by experiences of others.

Vibratory Test

Study of molding sands with the Jefferson Union Company was initiated with the vibratory test. This consisted, essentially, of adding a small amount of sand, with sufficient water, to an oil bottle and agitating the mixture by the means of a vibrator. Through differential settling qualities, the components were divided into strata and could be designated in terms of per cent by volume. The inadequacy of this method may be expressed by the following points:

1. The sea coal is not sufficiently separated from the clayey mass as to indicate accurately its relative proportion.
2. The distribution of the bond or its spread on the silica grains is not indicated.

*Jefferson Union Company.

Discussion of this paper begins on page 567.

3. The strength of the bond mixture is not shown. The presence of "dead" bond and fine siliceous matter gives a reading which may mislead.
4. The moisture is not revealed.
5. Permeability is not shown.
6. A fairly long time is required for the clay to settle to a constant volume.
7. The separation of the sand and colloids is incomplete.

The vibratory test seemed more applicable to new or green sand tests, especially since the writer wished to relate the volume per cent to sand strength. The difficulties in removing clay according to the standard A. F. A. method are well known. Errors are liable in the flotation of small silica particles, incomplete separation from the clay and mechanical losses. This renders the clay per cent, by weight, liable to considerable inaccuracy from these sources as well as incomparable due to its variable nature.

It has been found, however, that the volume per cent gives as satisfactory agreement with the Dietert shear test as the per cent by weight. The ratio of weight per cent to volume per cent, as being roughly an index of the aggregate density of the clay, has shown no definite relationship to the above test.

Permeability

In conjunction with the effort to forecast the properties of a sand, advantage was taken of data showing the variation of permeability with the screen size of the sand. Attempts to express this relationship by a parabolic equation were unsuccessful. A reasonably accurate constant could be determined for the finer mesh material but not the coarser. It is believed that this discrepancy is due to the greater variation in size of grains in the larger meshes. Complexities arising from a mixture of sand grain sizes are obvious.

Data somewhat similar to the above but relating the amount of clay content by weight to permeability, show curves which may be taken as straight lines up to a clay content of 10 per cent by weight and more particularly so in the finer meshes. The slope of the line or permeability drop is sharp in the coarser sands and less so in the finer, in proportion. With more than 10

per cent clay a temporary increase in permeability occurs which has been described elsewhere as the clay permeability critical values.

Cold and Hot Permeability

In order to express some characteristics of molding sand, we are accustomed to make use of the coined terms, "cold permeability" and "hot permeability." "Cold permeability" signifies the meaning of the expression "permeability" as usually employed. "Hot permeability" is that of the sand as obtained by the passage of 2000 cubic centimeters of air through a standard specimen of sand, while it is at such temperatures as experienced in a mold at pouring period. The conception is merely one of raising the sand to working temperatures instead of that of the room. A negative permeability, or back pressure, can usually be expected, due to the expulsion of gases in the nature of steam, air, carbon monoxide and possibly carbon dioxide. This condition is aggravated by the presence of organic matter, sea coal and water. The latter is most important, not only on account of its quantity but because of its rate of evolution. Air, of course, increases in volume in proportion to temperature rise as well as the gases derived from the sea coal.

Often a sand is designated as having a "cold" permeability of a certain amount while its "hot" permeability may be considerably smaller in proportion. This may be due to a large clay per cent which is retentive of moisture and is a potential, gas-forming ingredient.

If, in a small mold, weighing 65 pounds of sand, 3 per cent of moisture is driven off, 52.2 cubic feet of steam, measured at atmospheric pressure, are derived from this source alone. Added to this, are the gases from the oxidation and distillation of sea coal plus the volume resulting from the air driven from the mold and due to the thermal expansion.

The volume of gas formed, is significant only in its respect to the pressure created, and this exists due to the friction of passage through the mold. Nearest the casting the static pressure is at its maximum and on the outside a minimum is approached. Even this minimum may be considerable and every

foundryman is familiar with the jets of burning carbon monoxide gas issuing from vents under no small pressure.

While the instantaneous value of hot permeability is interesting, it is of greater significance to learn the cycle of the sustained pressure or negative permeability value to which the liquid casting is subjected. The maximum back pressure may be large but decreases rapidly, due to a high cold permeability and no unsatisfactory results may occur. A less negative permeability with a longer sustained period may be disastrous. Yet again, a maximum negative permeability, because of its time position may be the feature to create damage. All of this relates to other variables in the metal which concern the period of liquidity, rate of freezing or the ability of the molten metal to absorb and expel the gases previous to solidification.

Blow Hole Formations

As opposed to the natural tendency, sand problems should not be treated independently of metal conditions. Experience has shown that the two are inherently related and possibly more so than we generally appreciate.

When the molten metal enters the mold, cooling occurs rapidly from the first incident. With this cooling, there occurs shrinkage of the liquid, increased viscosity, decreased solubility for gases and finally solidification which completes the lasting form of the casting. Unhappily, for ease of control, these actions do not occur within equal periods throughout the section of the metal. On smaller sections, cooling may ensue so rapidly that the dissolved gases are not evolved,—sufficient time for equilibrium not being permitted. Or, if the outer part reaches solidification while the inner part is molten, gases may be liberated there and seek the portion of the casting with least metallic pressure or greatest solubility. These portions are those of greatest section or least area of thermal emissivity, or in other words, of the highest temperature. The use of chills at these parts to prevent excessive gas liberation is well known to foundrymen. Shrinkage and low pressure sections are synonymous.

Analysis and temperature of the iron relate to these condi-

tions. Higher temperature decreases viscosity, decreases the original gaseous content of the metal, increases rate of initial cooling and time to reach solidification. Lower carbon analysis causes increased viscosity, greater gas solution and decreased time to attain solidifying temperature. All of these vary within limits of individual melting technique.

The relationship of the molding sand to the metal condition exists in that both must expel gas starting from the early part of pouring the mold until the casting is solid. If, due to a low hot permeability of the sand, a large back pressure exists at the time that the dissolved gas tends to issue from the metal, this gas may be retained in the casting. If the surface of the metal freezes before the back pressure is lowered sufficiently, blow holes occur, their position as internal or external, being indicative of the pressure-time relationship. If, however, maximum passage of gases from the sand occurs previously or following the period of expulsion from the metal solution, the liability of blow holes is decreased. It is to be remembered that the position of the period of gas-evolution from the metal is highly variable to several factors and likewise the extent of time which this includes. That of the sand is probably fairly constant in the same measurement.

The writer has been assured, by those of longer foundry experience than himself, that excessive permeability is possible under certain circumstances. From a theoretical standpoint there is the possible effect of penetration of the metal into sand grains because of improper support to the fluid and a too rapid gas liberation from the casting resulting from lack of adequate pressure. These possibilities are contingent, at least.

Misruns may be often a result of low permeability plus low fluidity of the entering iron. Excessive chilling with the latter factor may produce this condition.

In the case of question as to the source of gases as derived from the metal or mold to cause surface defects, the presence of an oxidized surface in the holes would suggest that the condition is due to steam from the sand. Other agents may produce this, so an opinion should be formed only after due consideration.

Sand Holes

Data taken over a period of time have shown that high green strength and moisture causes sand holes. Well tempered sands, in other words, are prone to this type of scrap. Increase in clay content likewise aids this tendency. The mechanism of sand holes is evidently related to the expulsion of moisture from the bond, and there is little doubt but that the violence of this action explains its inclusion in the metal. The liberated steam causes a hole or depression in the iron as a witness of its previous occupancy.

Liberation of steam is injurious only when such instantaneous pressures are built up that they react upon the molten metal. In a similar line of thought, if the pressure gradient from the inside of the mold to the atmosphere through the risers is great or local flow resistance is small, the rapidity of the gaseous flow may be such as to disrupt the mold. Sand holes are then liable. Other investigators have reported that by slowing down the out-rush of gases from the vents of the mold during pouring, the formation of sand holes is lessened. The velocity pressure of the air and steam is cut down sufficiently that the sand particles are not dislodged in this process. This appears the most plausible explanation in agreement with observations.

Microscopic examination of so-called "slag holes" has revealed that these are essentially sand holes with the silica particles attached to the casting by the fluxing action of iron oxide on the bond. This explains the statement of the practical foundryman that, "The slag was made in the mold." The black appearance of this slag disguises the silica, making its identification more difficult.

That defects can occur due to furnace slag actually entrapped in the metal sounds thoroughly possible, although we have never seen such inclusions. As slag is a brittle material the tumbling and cleaning process would remove such before they could be inspected. The low specific gravity of furnace slag bringing it to the surface makes the probability of such defects rather remote. The cleanness of acid open hearth steel bears a similarity to that in the air furnace.

Tests of New Sands

Testing of new sands is made substantially as outlined in the A. F. A. Standard Methods.

An addition to this practice is the determination of the clay per cent by volume following a definite vibration and settling period in a sodium hydroxide solution. Advantage of this alkali solution is taken to determine the approximate organic content from the coloration of the supernatant liquid. This is compared and expressed in terms of arbitrary standards of a certain range. These standards are made up of different proportions of caustic soda and tannic acid which are sealed air-tight to arrest oxidation and consequent change in color.

Every carload of sand entering the foundry is sampled and tested. If lot inspection by sand foreman leads to any question of suitability, a preliminary sample is taken by inserting a pipe sampler throughout the carload and obtaining sands corresponding to each cross section. Emphasis on sampling is stressed as the validity of the tests are directly dependent on it.

Adaptability of various kinds of sand to different work is taken into consideration in their application. For each work a type of specification may be drawn up as a guide, limiting the range in values estimated from experience. In the case of coarse, natural sands, a greater variation in properties may be expected and taken into consideration.

Since there exists a variability in hand ramming, we have found it advisable, on occasions, to make compaction tests on new sands or mixtures. This consists of plotting the curve of increase in green strength or decrease in permeability with each additional ram. A fairly flat curve such as might be expected from a sand of fairly uniform grain size, shows that it may be rammed hard with impunity. However, some additional bond may be required to care for the possibility of too light ramming.

Routine Sand Tests

In order to maintain adequate control over the condition of the molding sand, tests are made daily on backing sand from each floor and each batch of facing as delivered from the prepara-

tion room. The green strength, permeability and moisture are run for each sample. Once a week the dry strength of the backing is taken. The working fineness of each heap, (i.e. that with the clay unremoved from the sand) is taken at intervals, circulating to all the floors then repeating the cycle. This acts as a check for change in grain size or agglomeration. Special tests are made, as seems desirable.

The importance of testing facing sand should be emphasized since this is the material lying nearest the iron and most significant in its action. The backing sand should have a high cold permeability while, in the case of the facing sand, hot permeability is equally or more important.

Equipment used in sand testing consists of the permeability machine and the shear test. The latter is to be replaced shortly by a compression machine. A swing pendulum type sifting machine for the fineness test has been found to give good performance. Moisture is determined by drying out the permeability sample while the shear strength specimen is made up in an aluminum core box.

New Sand Additions

Green sand additions should be based essentially on shakeout loss;—experience having indicated that in average malleable work the decrease in strength can be adequately met by these amounts. A general rule to follow is to make minimum additions to still maintain an adequate green strength. If excessive quantities of new sand are added, the practical life of a unit amount is decreased, due to more repeated exposure to the high temperatures of the hot castings.

Coincident with higher scrap loss accompanying greater green strength, we have found mulling to similarly increase scrap. However, this may be avoided by mulling only a part of the heap and obtaining an average strength of the proper order. Parallel to this reasoning, it is desirable to make new sand additions in the facing sufficient only to acquire the desired strength. The capacity of new sands to retain water together with their proximity to the hot metal results in a large steam formation in the most undesirable part of the mold.

Moisture Content

Based on our experience, "optimum," as applied to moisture content, is of incorrect nomenclature. The actual "best" value is somewhat less than this. In fact, with a given clay content, the least moisture to insure workable properties is most desirable. During the course of some studies of molding sand, the preferable term "critical point" has been used, i.e., "a permeability critical point" and "green strength critical point." These avoid the confusion and misunderstanding from the inapplicability of the previous name.

It might be pertinent to mention here that a clay permeability critical point exists, wherein, at certain contents, the curve of decreasing permeability with increased bond breaks. At this point a hump occurs, showing a temporary jump in the measured openness of the sand; after which the sand curve resumes its normal relationship with the continuation set over somewhat from the original curve. The proportions of this hump increase rapidly with higher moisture content, rising beyond the initial value with about 9 per cent water. While the clay content producing this is beyond the range of foundry applicability, these curves are of value in explaining the mechanism of sand factors. The exact cause of this has not been determined, but it might be suggested that this critical value represents a point where the expansion of clay due to moisture absorption is greater than can be taken up by the voids between the grains and so an expansion of the entire mixture occurs with resulting greater openness.

Since, as is generally known, higher moisture results in increased scrap and the clay content does likewise by virtue of its retention of water, the question arises as to whether one of these is more desirable than the other. Higher clay content, permitting of lower moisture of physical combination, has the disadvantages of requiring a longer tempering period, giving more rapid destruction of the bond, greater tendency to burn onto the casting, a delayed moisture evolution during and following pouring together with a lower cold permeability. High moisture with lesser clay content has a rapid and hence inconstant moisture evaporation—varying with weather conditions and length of stand-by period.

There is also a more rapid evolution of steam due to heat from the molten metal, with resulting higher pressure within the mold. The writer's opinion is that clay content is more difficult to maintain at a fixed value and should, therefore, be high enough to allow of relatively low moisture yet, in itself, approach the minimum as closely as possible.

It is generally undesirable to saturate the clay bond of a sand beyond the external layers of contact. Further moisture decreases the hot permeability and increases shrinkage on drying with possible resulting strains within the sand.

If a high clay content sand briquette is heated rapidly, the evolution of steam may be so violent as to shatter the piece with explosive effect. An idea of possibilities within the mold may be appreciated. Actually, some back pressure effect comes into play as was mentioned under sand holes.

Efforts to determine the cause of sand holes in our practice led to the gathering of various data which indicated increased sand holes with greater green strength. Further investigation revealed an even more traceable relationship to moisture,—hence, greater green strength. To formulate a theory was next, and this led to a tie up of the propulsive action of steam, as given above, with this particular source of scrap. It seems highly probable that grains of sand are actually impelled into the molten metal by the suddenly liberated steam.

The retention of moisture otherwise than is affected by weather conditions is dependent on the openness of the sand, clay content and the absorption value of the clay.

Well tempered sands have been found to be more productive of scrap than those less effectively tempered. This is probably due to greater absorption of moisture with consequently more violent expulsion when the metal is poured. This condition is more pronounced following a holiday or week end, but the cause is difficult to differentiate from after-effects which are peculiar to molding labor of today—possibly of yesterday. Usually, sand floors are liberally sprinkled with water and permitted to stand over the holidays. Better practice is to cut over the sand only

on the night previous to resumption of operations. We have observed lower scrap losses thereby.

Clay Content

In order to obtain the best results from our molding sands, we have found the best practice is to employ the least clay possible to insure a consistently workable sand. The degree to which the minimum may be approached depends on conditions peculiar to each situation, but I strongly feel that this rule is generally applicable.

For the study of molding sands we have found the microscope of great advantage, insuring accuracy and swiftness of examination. Grain distribution may be observed without the tediousness of the more accurate base screen tests. Spreading and uniformity of bond distribution is revealed and objectional minerals identified. The information obtainable by a careful inspection of this sort may be worth a fair series of tests. Study of the separated bond itself is possible in this fashion.

In general, "burnt" or dehydrated clays readily absorb and retain moisture and are as undesirable as the plastic clays in this respect. There is a difference, however, in various clays, in the extent to which this absorption can take place. This pertinent feature promises to solve certain problems for the future.

Sea Coal

Recourse to available literature has given us no information relative to the action of sea coal in giving a smooth surface to casting, otherwise than by the formation of a gaseous layer adjacent to the mold surface. Obviously a similar condition could be produced by lowering the permeability.

By observation of cored castings, an especially bright and shiny surface is apparent, evidently produced by the gases from the core oil. In common with those from sea coal, these gases are reducing in character. Castings which are quickly shaken out from the sand and exposed to the air are always adherent to sand which can be removed only with difficulty. Examining such surfaces under the microscope, we found tiny silica particles

attached to the iron by a black material which we identified as slag or iron silicates.

The mechanism becomes apparent. Under oxidizing conditions, such as exposure to air or absence of reducing gases, a very thin film of iron oxide forms on the casting surface. This is basic in character and with the high temperature involved this eagerly combines with the silicates present as clay to form slag or even with the small silica fragments themselves. In the presence of a reducing atmosphere, the thin film of iron oxide is prevented and no reaction to form these complex silicates is liable.

The reducing quality of sea coal is most effective in sands that are not too open, since the rapidity of burning out of the coal depends on the openness of the sand as well as the temperature of the metal and size of the casting. If the quantity of sea coal is increased, this soon becomes objectionable due to the tendency to cling to the clay bond and act as a diluent as to the green strength. The volatile matter is readily distilled off, but the carbonaceous residue is less readily converted to gases and accumulates without adding so much protective effect. If large amounts of sea coal are used, the characteristic grape vine surface to the casting is produced.

In opposition to the reducing gases, carbon dioxide, water and atmospheric oxygen are oxidizing agents. Highly bonded sands carry the most moisture and fluxes and can thereby be expected to give a poorer surface accordingly. Certain clays are more potent than others in both respects. Our studies have shown rough surface of castings to increase with higher green strength which is a reflection of greater clay content and temper or tendency to agglomeration.

Dry Strength

The dry strength of a sand is often assumed coincident with the condition of the sand when adjacent to molten metal. Although this is not strictly true, there is no doubt but that the dry strength is an approximate measure of this state. The actual difference exists in that some of the chemically combined water of the clay is driven off at the higher temperatures. Just what occurs is best illustrated by severely heating a sand test briquette

on a red-hot plate. It will be found, on cooling, that the briquette disintegrates readily at one's touch. This is a function of high temperature rather than time. The reason for this weakness is disintegrative shrinkage. If the sand is heated to 220 degrees Fahrenheit, shrinkage of the entire mass takes place and the extent is not increased by further heating. However, on raising the temperature, further shrinkage does actually occur between the grains themselves, within the mass. Because of the low bonding power between the particles, the sand is disrupted and cannot shrink as a unit.

The logical reply to the above would be that such a disintegrated condition is probably not reached in the early stages of pouring where the tearing action on the sand is at a maximum. This is undoubtedly true, but in large castings where the filling out of the mold is relatively slow, this answer does not apply. The tearing or abrasive action is less severe, fortunately, on those parts of the mold interior which are longest subjected to the intense heat.

An excessively high dry strength is objectionable. If circular work is made using a green core, the sand may set so tight as to compare with a baked core in strength. The metal shrinking upon this may be cracked due to the strains at high temperatures at which the tensile properties of the iron are low. A casting of varying cross section is even more liable, as the strains resulting from differential cooling of the section may be additive to this.

With constant clay content, an increase in moisture content increases dry strength at the expense of both hot and cold permeability. The former occurs due to retained water, and the later because of increased compaction taking place on ramming, together with other phenomena.

Ordinarily, the distintegration of the bonding of the sand layer may be considered as productive of sand holes and wash effects. In certain large work, however, we have observed a spalling off of rather large pieces of sand when the bond was fat clay in quite large quantities. This was attributed to the high shrinkage of the clay in those parts subject to a high temperature over a fairly long period of time, with the sand unsupported by

the liquid metal at time of fracture. The top of the mold would be of this description so that the flaking off would result from differential contraction of the sand near the surface and that beyond this where the action would be less severe. Projecting parts with drying surfaces of variant dimensions are most likely to this form of failure.

Feel of Sand

The method of determining the nature and condition of molding sand by the feel is an old art, but one subject to certain errors. Although the experienced foundryman takes these features into consideration, it is well worth while to enumerate the possibilities.

Sands which are warm tend to feel more moist because of the water vapor which is evolved and condensed on the palm of the hand. Sands which have had a long temper are greasy to the feel and may have similar characteristics to sands of higher moisture and less period of temper.

One of the difficulties in estimating the coarseness of sands is that the apparent fineness appears like that of the coarsest grains since these produce the greatest tactile sensation. On the other hand, presence of a considerable amount of fine matter may not indicate itself. Sands free from clay feel coarser than those containing bond. Agglomeration will also increase the apparent coarseness.

Different clays have a different feel, and it is necessary that the sand foreman adapt himself to this difference for proper judgment of their condition.

It is fitting, I feel, to mention that the sand laboratory has been found to coincide to a surprising degree with the opinions of the practical foundryman. Often many ideas and expressions have seemed absurd but study has revealed that they were essentially on a rational basis, although the description was occasionally inadequate or inexact. Credit is due these men who created the art before it aspired to a science.

Gating

Recent experience tends to indicate that gating is responsible for many of the ills laid to sand or metallurgical features. Since

the speed of pouring vitally affects the rate of gas evolution from the mold as well as the rapidity of freezing of the iron, once the mold is filled, this influence seems most possible. There is probably existing a definite gating arrangement which is best for the type of sand used and changes in one will reflect on the behavior of the other. Observations point strongly to this.

Removal of Fines

The removal of silt from molding sand appears as a very attractive proposition, but some practical difficulties exist. First, I might arbitrarily define silt as very fine material, say that passing through the 270 mesh in a test sample.

The use of screens to remove the total silt is, on a practical basis, out of question, since large screens of the small mesh required are not of sufficient mechanical strength to stand the necessary vibration. Furthermore, the speed of action for handling sand of sufficient tonnages is too rapid for complete removal of this fine matter. To insure the best working conditions it is necessary that the material be dry, and if the silt is not sucked off by some means, dusting will re-add as much fines as is separated originally. Coupled with air separation, however, the removal of fines in this fashion seems thoroughly feasible.

Molding sands may be made more open by combining screening with other operations. If part of the "through" material from the screens is rejected and the rest added back to the "on" material, the new mixture will have a lower average fineness number, i. e., be coarser.

One important advantage of mechanically operated screens is their use to remove shot, old cores and extraneous matter in sand which is to enter the muller. The advantages from this are freedom from undesirable content and better working of the muller. Less wear on the muller parts is obtained and the plows may be set low to obtain the most efficient mulling action from the standpoint of uniformity. This is important, as the muller requires good operation to develop the qualities of the sand.

Rebonding

Our experience with synthetic molding sands has been slight but we have been forced to make application of these in order to obtain a sufficiently high permeability which is necessary for certain classes of work that we make.

Appreciating that by merely mulling a sand without clay addition the green strength is increased, an effort was made to learn the reason of this increment. By disintegrating the sand with a sand cutter of the traveling belt type, the strength was but slightly decreased. Examination through the microscope revealed what appeared to explain the phenomenon.

The effect of heat of sufficient intensity causes a thin crust of clay adhering to each grain and, either due to greater density resulting from shrinkage or other phenomenon, resistance to moisture penetration is increased. The effect of mulling is to break down this layer and expose more absorbent material to the water present. More rapid tempering occurs, and the latent, adhesive qualities of the underlying clay is so developed.

In order that the clay addition to the sharp sand could have a foundation to further their adherence, resort has been had to the inclusion of a quantity of natural sands. This rapidly reduces the permeability, but was thought to be necessary. Experiments made in a laboratory muller showed that certain bonding clays are quite resistant to this initial adherence, while others were less so. By properly blending these clays of different characteristics, a sand was obtained which possessed the wanted characteristics of adequate strength and high permeability.

Acknowledgments

The writer wishes to express acknowledgment to Robert E. Bryant, vice-president of the Jefferson Union Company, for the permission to use the data on which this paper is based. He is also particularly grateful to him for the aid and encouragement which has rendered this work possible. To Francis E. Stahler credit is due for the greater part of the laboratory work involved.

Efficient Steel Casting Grinding

By F. A. LORENZ, JR.,* EAST CHICAGO, IND.

The subject of efficient grinding of steel castings might be enlarged to embrace the whole foundry group, as it is the generally accepted method of removing excess metal from the rough casting to make it suitable for its final application or for the machining operation.

Grinding methods in all foundries are constantly undergoing changes as the builders of grinding equipment are redesigning their machines to provide more power, rigidity, bearings and other characteristics which have helped to lower the cost of grinding. In a large measure reductions have also been effected through the progress made by manufacturers of both vitrified and vegetable bonded grinding wheels. It has been a combination of the foundries demanding more efficient operation and lower grinding costs, particularly for alloy steel castings, which has resulted in better design of machines, greater production and improved types of grinding wheels.

In a number of steel foundries, the subject of grinding has been given attention from a really scientific engineering viewpoint. Engineers and foundrymen were quick to realize rough steel casting grinding was just as much of a machine operation in the foundry as any other machine operation. Careful study has shown the results to be obtained were largely dependent upon the service to the machine as well as the combined operating characteristics of the machine and the grinding wheel. In other words, to

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Discussion of this paper begins on page 636.

procure efficient operation it was necessary to keep grinding wheels in contact with the work the greatest possible time during working hours. Therefore, the study of service to the machine and to the operator became a very important phase of the grinding problem. It was found that good floors for the operator, correctly designed trays, racks, buggies, etc., for bringing the work to and taking from the machines, were very necessary.

Without changing the characteristics of the machine or the grinding wheel, it has been found that by just giving the grinder efficient service and bringing the work to him in a properly designed container, giving him continuous work and service enabling him to dispose of the ground castings, the efficiency of the unit has been increased as much as 30 per cent. Of course it must be realized that this can only be possible in cases where it is practically up to the operator to provide his own source of supply for grinding castings and disposing of them.

The Grinding Wheel Only One of Several Factors to Be Considered in Efficient Grinding

In approaching the subject of grinding castings, too often the only factor in the situation given consideration has been the grinding wheel itself, when the subject of a comparative service test of various makes and grades of grinding wheels is under discussion. The grain and grade of the wheel is often varied up and down. The grinding wheel manufacturers' experts have been in on the job and they have tried this grain and that grade of wheel. They may have suggested a change of equipment to the foundryman, but too often a deaf ear is turned to these suggestions and the foundries insist on going along with antiquated machinery, inadequate peripheral speeds and wheel changes or speed changes to provide the most efficient cutting speeds. By rearrangement of their department, giving service to modern up-to-date grinding wheel equipment, reductions in costs can be made which are truly remarkable and will more than substantiate the cost of the changes.

Layout Should Be Considered

The problem should be approached in its entirety. First, the question of layout should be considered.

Is the movement of the work to and from the machines as direct as possible?

Are the types of containers or the layout of the work for the grinders efficient?

Is the grinding unit flexible enough to take care of the class of work to be handled?

Is the operator able to do continuous grinding or is he constantly interrupted?

Are the grinding machines themselves efficient?

Are they under-powered?

Is there proper lighting, heating and ventilation in the cleaning room?

All of these subjects have their influence on the problem.

After all of these factors have been considered and a layout determined, which will give the best service possible to the operator of the grinding machines, then the question of the proper type, grain and grade of wheel may be properly considered.

When all of these factors are taken in combination and the grinding department properly laid out, or in most cases with the present grinding equipment in the foundries completely revamped, the results which will be obtained are truly astounding.

Some Actual Results

It is only necessary for me to quote here something from our own experience to indicate what can be accomplished by a study of the grinding problem.

In a cleaning department where large castings are chipped and ground, the grinding equipment formerly consisted of eleven swing frame grinders belt-driven from a line shaft. These grinders were the type which were hung from a side wall bracket, hinged at the top and in the center, which gave them a limited radius of operation of approximately two feet front and back, and three feet to either side, and such upward and downward motions as the operator was able to control by his own strength. This type of swing frame grinder was in vogue in foundries twenty years ago, and is still continued in many foundries today. They were used for grinding down the stubs of large risers and in many cases for removing irregular stubs of fins which had been knocked off by sledging.

In previous tests it had been the custom to take different makes and grades of grinding wheels and compare them one

against the other, for pounds of metal removed per contact hour, running them at speeds which the wheel manufacturers and the foundrymen knew were inefficient, but due to physical limitations of the machines, wheel changes were not made at the point to insure efficient grinding. No thought was given to the machine, no thought was given to the time consumed bringing the work to the grinders and then removing it, or the delays occasioned to adjacent grinder operators when work was being placed by overhead crane. The efficiency of the machine, power losses and high maintenance expense due to poor design were lost sight of in the test. The limited radius of action caused many unnecessary movements of work and constant delays to the operators, so the actual contact time of the grinding wheels with the work on an average day showed an efficiency of less than 50 per cent, and in many cases, due to the character of the work, as low as 30 per cent.

These figures to the uninitiated may seem very low, but it is no wild guess, on the part of those who have gone through similar studies, to state if the average foundry manager will take these factors into consideration and make a study of his particular grinding problem, he will find that the above efficiency figures hit the general average for a foundry doing miscellaneous work.

The problem of grinding in the particular department was then considered in its entirety and it was decided the 11 swing frame grinders could be dispensed with and replaced with two up-to-date high-speed grinding machines, which could be hung on a side wall crane, manipulated from the floor and traversing a space 40 feet long by 20 feet wide. The whole machine was hung so that it had a radius of operation of 360 degrees and an up and down movement of 8 feet. The floor space was all clear. The results of installing the new machine and the handling equipment exceeded the expectations, as one operator is now doing the work with ease which was formerly done with five and sometimes six operators and machines. His work is laid out in such a manner that the only time lost is the time consumed in raising and lowering the grinding machine by a hand operated chain block or moving from one piece of work to the other by means of the electrically operated side wall crane.

Work is brought to the grinding wheel and laid out in such a manner that it is most convenient for the operator to grind,

with the net result that the grinding cost, taking into consideration cost of wheels, overhead, supervision, power, repairs, service, etc., has been reduced to one-third of the former cost. Specific details are given in Table 1, to show the comparative cost of grinding

Table 1
SUMMARY OF RESULTS

	—Best Performance—	
	Old Practice	New Practice
Average lbs. of steel removed per hour.....	8.8	40.4
Abrasive cost per lb. of steel removed.....	\$.063	\$.059
Labor and overhead per lb. of steel removed.....	.106	.022
Total cost per lb. of steel removed.....	.169	.081*

*This is now reduced in actual average practice to \$.070.

by the old and new methods. Here is a case where the foundry has gone to considerable expense providing new machines, costlier wheels and an extensive crane layout, yet the net result has been to reduce their grinding cost $66\frac{2}{3}$ per cent.

Improvements Can Be Made in Many Cases

The grinding wheel experts of the various manufacturers know of these improved methods and when they are approached in regard to the application of them in various foundries, they come back with the statement, "The company did not see its way clear to spend the money," yet the results are there and may be obtained by any foundry that will carefully study its grinding problems and solve them in the light of improved layout of machinery and grinding wheels.

The improvement which has been made in grinding machinery designed for foundries as well as the remarkable strides made in the development of grinding wheels for use on various types and analysis of castings, offers one of the biggest fields for investigation by the foundrymen and others, as the application of the improved methods, machinery and grinding wheels will surely result in one thing—a reduction in cost of cleaning castings when intelligently applied to a particular problem.

Comparison of Old and New Practice

In the attached table of results are indicated the best results obtained on the old grinding practice, and a composite figure of

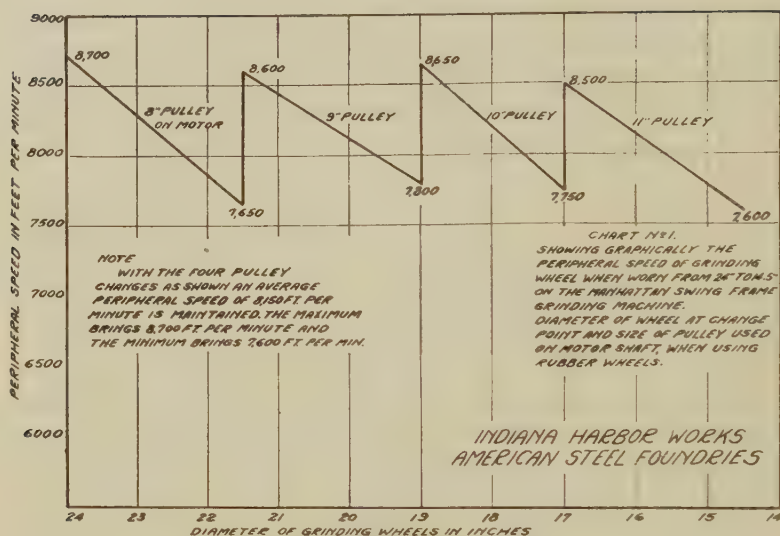


FIG. 1

the results obtained from trials of five makes of grinding machines which were substituted for the old machines. It is important to know the practice was changed from grinding with vitrified wheels, having a maximum speed of 6,000 surface feet per minute, to vegetable bonded wheels having a maximum speed of 9,000 surface feet per minute. Wheel changes were made at the points indicated by Fig. 1.

In considering the above table, no allowances have been made for the loss of time occasioned by the former practice where five grinders were working close together and were often delayed by placing and removing castings. It will be seen from the figures the average pounds of metal removed per hour are approximately in the ratio of 5 to 1. In other words, one operator now replaces five operators, so that the delays due to placing and removing of work have been reduced to practically a minimum. Under the new method actual total cost of pounds of metal removed is approximately one-half the best practice formerly obtained. Comparing the average cost as shown on the cost sheets, the present grinding costs in the department where tests were made is approximately one-third the former cost.

Shrinkage in White Cast Iron

BY H. A. SCHWARTZ,* M.E., CLEVELAND, OHIO

Synopsis

The paper concerns itself with the formation of porous spots during the freezing of white cast iron. The mechanism by which these spots are formed is first considered. The available data, both original and from the literature, regarding the changes of density at the freezing point of iron are briefly reviewed, a method for the direct determination of this type of shrink is described in detail and a series of results on commercial heats is given, showing that although carbon and silicon content affect shrinkage slightly there are variables of much greater magnitude which have not been worked out.

The paper has purposely been prepared entirely from a metallurgical viewpoint and no attention has been given to the designing of patterns which for a given metal will minimize the condition being studied, nor to the question of whether some metals will feed more effectively than others.

Introduction

An audience of foundrymen need not be told of the practical significance attached to a study of shrinkage in castings. For other engineers it may be well to say in passing that the importance is twofold. First, because the elimination of shrinkage is an economic factor in determining the cost of manufacture of castings, and second, because if shrinkage is not substantially eliminated it obviously affects the strength of the casting as a structural

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Discussion of this paper begins on page 663.

detail and is thus co-equal in importance with a physical specification in determining fitness of a product for its intended use. The problem in all its ramifications is vast, beyond the ability of analysis by one individual or in any one paper. Indeed, the aggregate knowledge possessed by the industry of this phenomenon is still but trivial as compared with the scope of the entire subject.

In the interests of brevity and also from limitations of knowledge the writer will in the present connection confine himself primarily to a scientific discussion of the factors resulting in that type of shrinkage which manifests itself by the formation of spongy or porous spots in white cast iron. He does not propose to discuss the methods of eliminating shrinks from particular castings or to attempt a discussion of the data pertinent to other materials. Shrinkage as understood by the pattern maker and as finding expression in the fact that the over-all dimensions of the casting are less than those of the pattern will be touched on but incidentally.

Common Conception of Shrinkage

We are accustomed to explain a shrink by saying that it represents the decrease in volume of the metal in cooling to room temperature from its molten condition. This explanation is perfectly sound so far as it goes, but disregards the need for an explanation of why this decrease in volume should manifest itself in whole or in part, as an internal void rather than a decrease in outside dimensions. Indeed, we know that the outside dimensions do decrease, necessitating a "shrinkage allowance" in pattern making. We also recognize cases where the surface of a casting "sinks" or "settles" to make up for this decrease in volume.

Further, we know that different castings poured from the same metal vary greatly in their susceptibility to "shrink" and the same casting poured from apparently identical metal may vary greatly in this respect from time to time. We refer this to temperature of metal, sand conditions, pouring rate, and so on, without any very definite conception of how and why such variables should affect the results. There is even good ground for believing that the answer to whether hot or cold poured metal will produce the larger shrinks is not the same for all castings, or for every gating of a given casting.

Some Hypothetical Considerations

In the further consideration of the problem, we may for the present assume that we have a metal whose coefficient of expansion is the same at all temperatures, from far above the melting point to atmospheric, and further, that it freezes sharply at a constant temperature, and without change of volume. We may assume also, a constant specific heat and a negligible latent heat of fusion. None of these assumptions are correct, but they will simplify the discussion, and consideration of how the real facts alter the preliminary conclusions can be had later.

Let us assume that we fill, instantaneously, a spherical hole in an infinite body (of molding sand for example) with our liquid metal, and observe the circumstances under which the latter cools.

Immediately after the mold is filled, the metal begins to give off heat to the surrounding mold, and from the symmetry of the system, we may assume that at any given time the temperature at all points of a (spherical) surface at a given distance from the casting's surface is the same. A more formal statement would be that in such a system, the isothermal surfaces are spheres, concentric with the spherical casting.

As soon as the metal touches the mold, its temperature decreases, due to heat transfer from the metal to the mold, at the surface, and conduction outward through the metal. The factors determining the actual form of the cooling curves at any point in the casting will be discussed later.

So long as the metal is liquid throughout, the decrease in volume due to cooling is made up by the metal sinking away from the top of the mold, which it then no longer fills completely. This results in a small flat spot at the top of the casting. This settling increases until a layer of solid metal is formed over the entire surface of the casting.

We are then concerned with a sphere of metal consisting of a solid shell and a molten interior, hotter within than without, and cooling from the surface. The flattening at the upper pole, which may have occurred while all was molten, is for the present disregarded.

If now all parts of the sphere cooled at the same rate, then in our ideal metal, all parts would also decrease in volume at the same rate, and there would be no tendency either for the cooling

surface metal to compress the liquid interior or for the cooling liquid interior not to fill the solid shell surrounding it.

In such a case, the surface would reach room temperature while the center was still hot. When the center had become cold, it would be smaller than the shell, and this difference in volume would have to be made up somehow. If the content could be assumed to be liquid for some time after the shell was at its final temperature, its decrease in volume would result in a void, a "shrink" within the casting. If, however, a shell of hot, but solid metal, intervenes between the liquid and the cold layer, then radial tensile stresses will be set up, tending to separate the metal along spherical surfaces.

In our hypothetical metal, without change of volume or heat evolution at the freezing point, the metal will freeze in concentric layers in contact with the surrounding solid; it being now assumed that this solid has reached room temperature outside, and the inner layers are rigidly attached to it.

The decrease in volume occurring during cooling to the freezing point will be represented by a gas bubble, or a vacuum within the frozen shell, which will represent finally, a void or shrink near to, but above, the center. A vacuum within might result in the collapse of the outer shell, under atmospheric pressure, and a "sink" in the surface. This would be unlikely in a sphere, but more probable in a flat plate casting.

Considerations of Actual Conditions

The condition where all parts of the casting cool at the same rate can never occur actually, so our very simple concept just described has no merit except as a preliminary picture. Actually, the surface cools rapidly at first, then more slowly until it reaches a temperature relatively little above that of the room, and then very slowly. The center cools rather slowly at first, then more rapidly, and finally, when the whole mass is fairly cool, quite slowly.

We thus find that at some time during the cooling the surface cools faster than the center, and at another, the center cools faster than the surface. In our ideal metal, during the former condition, the surface layers are trying to compress the center, which is

impossible. There will thus result tangential tensile stresses in the surface, and radial compression of the inner mass, which may rupture the surface, and if molten metal exists within, extrude a portion of this metal, or at any rate so strain the surface metal that the object cannot decrease in volume externally as it desires to do.

When, on the other hand, the center cools more rapidly than the surface, there results a shortage of metal to fill the available space, and radial tensile stresses result, or else the liquid portion in the center makes up the shortage by flowing into the space and leaving again a void or gas bubble.

If, at a later stage, the surface should cool faster than the center, which may be considered unlikely, such a void might tend to disappear.

We are here led to the important conclusion that, even in a theoretically perfectly simple metal, the fact that there are necessarily temperature gradients within a cooling casting, and that the cooling rates are different at different times and different points, will explain the formation of "shrinks."

Conversely, we are led to conclude that the more nearly the cooling rates at the center and surface of a casting are alike, the less the tendency to "shrinkage."

The temperature gradient is an expression of the loss of heat from the center of the casting through the surface. It is, of necessity, steeper the faster the casting is cooled; hence, a casting cooling infinitely slowly in a mold, heated to the temperature of the molten metal before pouring, would have no thermal gradients, and hence no "shrinks." This condition is approximated in a large casting poured with metal far above its melting point into a mold of low diffusivity.

Molten metal freezing in a crucible in which it was melted, without removal from the furnace, also approximates this condition and is known not to produce shrinks.

On the other hand, if our mold be filled with our simple hypothetical metal, exactly at its freezing point, the first abstraction of any heat will freeze the whole mass, and although stresses may develop, we can not have shrinks which involve the flow of molten metal.

Furthermore, although we can not have uniform cooling rates at all points in a casting, if we have the exterior cooling more rapidly than the interior, until the latter has solidified, we may later set up radial tension stresses, but can not form voids or shrinks.

Temperature differences will be greater in large castings than in small and in those of variable cross section than in simpler ones, hence, although the actual change of volume of a given molten metal from a given temperature to room temperature is the same, "shrinkage" will be greater in the large and complex casting, and less in the small and simple. All this, is, of course, strictly in accord with the knowledge of every observant foundryman.

It will be obvious, also, that cooling rates, after all points of the casting are below the freezing point (solidus), may be important from the viewpoint of thermal stresses, or cracks, but not from that of "shrinks."

For the purpose of simplifying the consideration of "shrinkage" a metal of certain ideally simple properties has previously been assumed. In practice these assumptions are never justified. The coefficient of expansion of a metal in the solid and liquid state is by no means identical.

Problems Involved in Securing Data

Data as to the specific heat of liquid cast iron and for the solid at high temperature are somewhat difficult to secure.

Finally, the cast irons with which we are concerned have not a sharp freezing point, but rather a freezing range, and have also a fairly large latent heat of fusion. Furthermore, gray iron is known to have a fairly large expansion on solidifying, and cooling, just under the solidus.

White iron is believed to expand slightly in freezing, by some authors, though the writer was unable to corroborate this on commercial white cast iron, and feels inclined to doubt whether such an expansion exists.

If liquid metal has a higher coefficient of expansion than solid metal, then, even if equal cooling rates could be obtained throughout the cooling sphere, at a time when the mass consists

of a solid crust and molten center, the molten portion will continue to decrease in volume more rapidly than the solid, and so form a shrink.

This difference in coefficients of expansion will, therefore, aggravate shrinkage formations, for to eliminate them the surface layers must not only cool faster than the center, so long as any molten metal remains, but enough faster to make up for the greater rate of contraction of the center. The relative rate of cooling required to just balance the conditions will be inversely as the coefficients of expansion at the temperatures of the solid and liquid metal.

Any contraction at the moment of freezing will further aggravate the difficulty. An expansion, however, may help it. As the surface layer freezes, and expands, it separates from the inner layer of molten metal, but this separation is eliminated as the next layer freezes, and also expands into place. If the outer layers are contracting rather rapidly as compared with the inner, the expansion at the moment of freezing will merely relieve a little pressure on the interior, and possibly reduce extrusion. Expansion during freezing would thus be a desirable property, as we know in practice, from comparison between gray and white iron castings.

Selective Freezing

In metals having a freezing range, so-called selective freezing occurs, in which first an ingredient of high freezing point solidifies, and then a more fusible one. The first freezing constituent (austenite) is deposited in a tree-like form, along the crystal axes, and called a dendrite.

These dendrites grow into the molten metal, and if conditions are such that a void does finally result, they form an interlacing mass whose interstices could no longer be filled, due to insufficient liquid. This fact gives rise to the "spongy" appearance of shrinks.

The iron carbon equilibrium diagram, especially if interpreted also with reference to silicon content, gives us very accurate data regarding the freezing range. In all alloys in which we are interested, freezing terminates at about 1150 degrees centigrade, and the range decreases with increase in carbon and

silicon content. Absolutely nothing is known as to the change of volume of any of our alloys at the melting point.

Density of Liquid Metal

A method has been described elsewhere¹ for determining the density of liquid metal.

The data of Table 1 on materials of cast iron composition were obtained by Arthur Gorton and M. M. Austin. The sulphur, manganese and phosphorus are such as occur normally in malleable practice.

Table 1				
Serial No.	Carbon Per Cent	Silicon Per Cent	Temperature Degrees Cent.	Density
17	3.00	.52	1375	7.16
			1450	6.93
			1500	6.76
18	2.80	.68	1365	7.03
			1450	6.76
			1500	6.67
20	3.45	.72	1385	6.99
			1450	6.88
			1500	6.80
19	2.34	4.39	1380	6.60
			1450	6.55
			1500	6.47
14	2.06	1.01	1375	7.15
			1450	7.05
15	1.95	1.00	1375	7.07
			1450	6.87
16	1.80	2.25	1350	6.74
			1380	6.74
			1450	6.69
11	1.80	1.07	1375	7.04
			1450	6.87
5	2.43	2.84	1375	6.73
			1450	6.72

It was found impossible to work with alloys low in both carbon and silicon owing to the "wildness" of the metal and the high temperatures.

With alloys containing 0.5 per cent phosphorus and over insuperable difficulties were encountered on maintaining the necessary electrical contacts at higher temperatures. It seemed most unlikely that Mn or S in commercial amounts would have a measurable effect.

¹ Schwartz, H. A., *The Determination of the Density of Liquid Cast Iron*, Industrial and Engineering Chemistry, Vol. 17, p. 647, June, 1925.

In the first four metals of Table 1 (the last four investigations) density figures were obtained at 1500 degrees Cent also.

This permits some opportunity of determining whether the density is a straight line function of temperature.

In these four specimens we find:

Average change of density between 1375° and 1450°	= .165	= .0022 per 1°
Average change of density between 1450° and 1500°	= .105	= .0021 per 1°
Average change of density between 1375° and 1500°	= .270	=
pro rata change between 1375° and 1450°	= .162	

Obviously the change is as nearly proportional to temperature as our observations will inform us.

We calculated that the density of molten iron at 1450 degrees Cent. is given by the expression

$$\rho_{1450} = 7.16 - (0.10\text{Si} + 0.07\text{C})$$

Si and C are the contents of these elements in *per cent*.

The equation is, however, accurate only within the range of carbon from 1.75 per cent to 3.50 per cent and silicon from 0.5 per cent to 4.0 per cent.

The change of density with temperature is, within the range investigated, a function of the Si and independent of the carbon content or the temperature.

Its value is plotted as a function Si in Fig. 1.

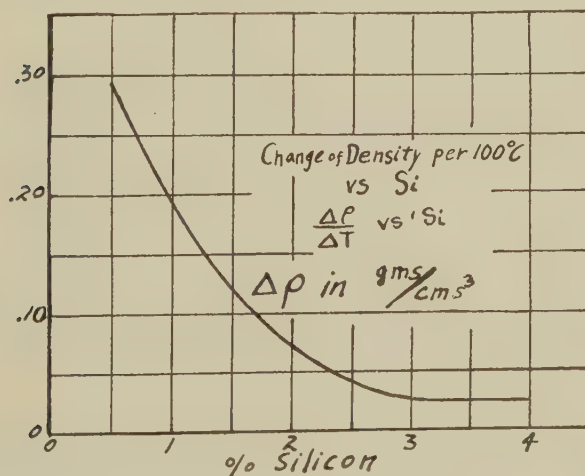


FIG. 1—CHANGE OF DENSITY (BY A. F. GORTON AND M. M. AUSTIN)

Density of White Iron

In 1918 the writer obtained figures for the density of white cast iron² at room temperature which indicated that the density was represented by the following empiric formula.

$$\rho_{20} = 7.94 - 0.08235 \times \% C$$

The formula corresponds to the assumption that the density of iron is 7.94 and of Fe_3C is 7.438. The density of white iron should be the mean of that of Fe and Fe_3C in the proper proportion to form the given carbon content and hence should be a straight line function.

It has also been repeatedly shown that the linear shrinkage of all nongraphitic iron carbon alloys not containing unusual elements is very nearly 2.1 per cent irrespective of composition. This is derived from the $\frac{1}{4}$ inch per foot shrinkage allowance always used.

The point where freezing is complete, or melting begins, i. e., the solidus, is at 1130 degrees Cent. for all alloys containing over 2 per cent C and rises rather rapidly to 1150 degrees Cent., with a small increase, say to 2 per cent in Si.³

We may probably assume that the volume at the freezing point, wherever that may be, $= 1.021^3$ times the volume at room

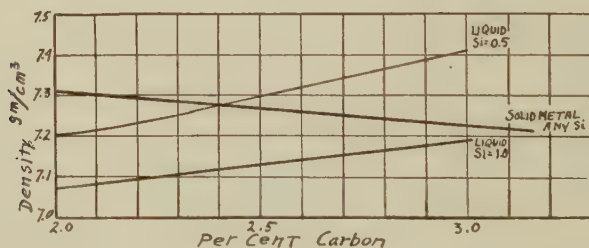


FIG. 2—DENSITY OF LIQUID CAST IRON JUST BEFORE FREEZING AND SOLID CAST IRON JUST AFTER BEING COMPLETELY FROZEN—BASED ON ESTIMATED DENSITY OF SOLID

² Schwartz, H. A., *Some Physical Constants of American Malleable Cast Iron*, Proceedings of the American Society for Testing Materials, Vol. XIX, Part II, p. 247, Fig. 8.

³ Gontermann, *Iron-Silicon Carbon Alloys*, The Journal of the Iron and Steel Institute, No. 1—1911, Vol. LXXXIII, p. 421.

temperature and hence that the density of the just completely frozen solid metal is

$$\rho_s = \frac{7.94 - 0.08235 \% C}{1.021^3} = 7.462 - 0.0774 \times \% C$$

This equation has been plotted in Fig 2 together with the Gorton-Austin data referred to for Si $\frac{1}{2}$ per cent and Si 1.0 per cent; carbon 2 per cent to 3 per cent; temperature the liquidus in each case.

There is here an indication that, depending upon composition, the completely liquid metal may be more or less dense than the completely solid metal.

The former is, of course, always hotter than the latter, the difference being 110 to 240 degrees Cent., approximately. The conclusion is qualitative rather than quantitative, for it is rather ill supported by conclusive evidence.

Our best direct personal knowledge on thermal expansion of hard iron is based on data obtained by the writer about 1908 or 1909 while observing the contraction of a specimen after freezing.

All white iron specimens were observed to contract .74 inches $\pm$.02 inch in 36 inches from pattern size during cooling to room temperature, irrespective of composition.

The shrinkage was observed to begin only below 1030 degrees Cent. The pyrometer was not calibrated by ourselves and it may be that the true temperature was higher. The contraction-temperature diagram was a graph of two nearly straight branches, the break coming at A_1 , which also was found somewhat lower than is to be considered probable.

An average graph, based on six specimens is shown in Fig. 3 and also the same data translated into percentage of the length at room temperature. Our data when compared with Tammann's formula⁴ for the change of volume on freezing gave impossible

$$\left(\frac{dv_s}{dT} - \frac{dv_l}{dT} \right) T_m$$

results especially in the case of the lower silicon irons. Others

⁴ Tammann, *Lehrbuch der Metallographie*, Dritte Auflage, p. 38.

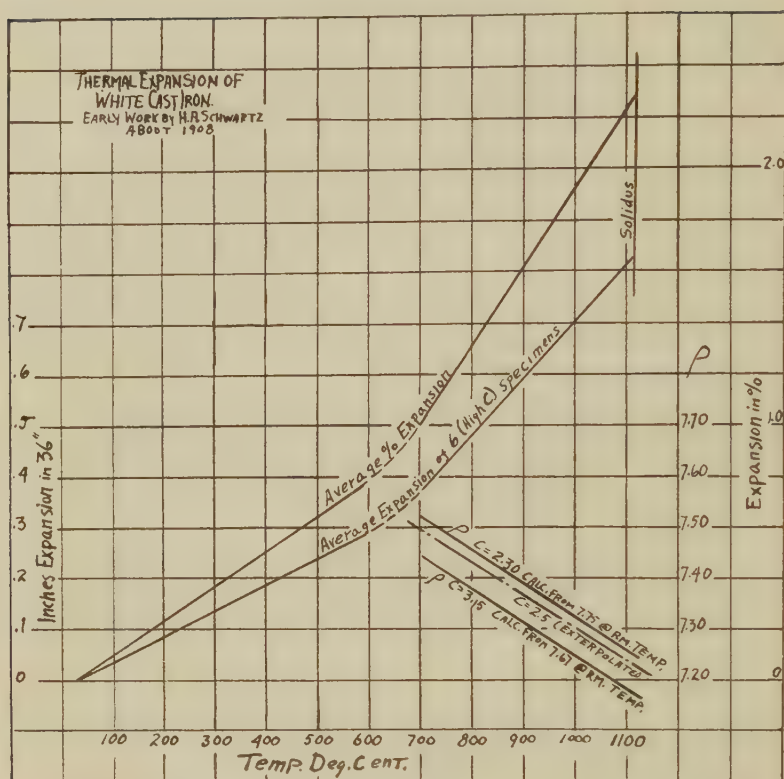


FIG. 3—THERMAL EXPANSION OF WHITE CAST IRON

have examined the problems more effectively but unfortunately with contradictory and inconsistent conclusions.

Change of Volume During Freezing

Honda and Endo⁵ have investigated, by the Archimedean method in fused NaCl the change of volume during freezing (melting) of cast iron.

They conclude that the change of volume is mainly dependent

⁵ Honda and Endo, *On the Volume Change in Cast Iron During Solidification, with a Criticism of the Double Diagram of the Iron-Carbon System*, Science Reports of the Tohoku Imperial University, Vol. XVI, No. 1.

upon the graphite content being but slightly dependent, if at all, on the silicon. Their results were as shown in Table 2.

Table 2

Carbon, Per Cent	Graphite, Per Cent	Silicon, Per Cent	Δv
			$\frac{v}{\text{Per Cent}}$
4.3	3.08	2.03	1.65
4.2	3.06	2.31	1.66
4.2	2.80	1.28	1.18
4.1	2.20	0.44	0.47
4.1	2.06	0.38	
4	1.17	0.08	1.76

By extrapolation they conclude that, in the absence of graphite, the change in volume would be a contraction of 3.60 per cent.

They call attention to Benedicks' and Westgren's work on the density of liquid cast iron and the space lattice of δ iron and calculate a contraction, during freezing, of pure iron of 4.4 per cent by volume, whence one concludes that the presence of carbon slightly decreases the contraction, assuming the Japanese and Swedish data to be comparable.

They investigated also the density of various cast irons containing 4.1 to 4.3 per cent carbon and 0.8 to 2.3 per cent silicon at various temperatures in the liquid state.

Their results for the different irons seem to have been considered so nearly concordant that they might be represented by average values for the series of Table 3.

Table 3

Temperature Degrees Cent.	Specific Volume, cm ³ /g
1300	0.1480
1250	0.1460
1200	0.1445
1150	0.1435
1130	0.1433

It will be seen that the change in specific volume per 50 degrees Cent. temperature interval, increases quite rapidly with the temperature and quite regularly, being 0.0005, 0.0010, 0.0015, 0.0020 for the four intervals in question.

Writing v for specific volume, T for temperature above the eutectic melting point, we may write

$$\frac{dv}{dT} = 0.00001 + 0.0000002 T$$

hence

$$v = 0.00001 T + 0.0000001 T^2 + 0.1433$$

since $v = 0.1433$ when $T = 0$,

and this equation represents very nearly the relation of temperature above the melting point to specific volume of cast iron.

Sauerwald and Wecker⁶ have published data obtained by similar means. They found that a white cast iron containing 4.15 per cent carbon and 2.2 per cent manganese and apparently only traces of other impurities, had a density at the melting point in the solid of 7.15 and as a liquid of 7.05, the corresponding specific volumes being 0.1398 and 0.1418 respectively, corresponding to a contraction of about 1.4 per cent in volume on freezing.

A gray iron containing 3.32 carbon, 2.72 graphite, 2.76 silicon, 0.56 manganese, 0.126 sulphur and 0.49 phosphorus, was found to change in density from 6.90 to 6.97 on melting, corresponding to a change in specific volume from 0.1449 to 0.1435, an expansion in freezing of about 1 per cent.

Sauerwald and Wecker find the specific volume of their white iron to be 0.1293 (± 0.2 per cent) at room temperature which rises to 0.1390 to 0.1404 at about 1115 degrees Cent. The metal thus expanded about 8 per cent in volume on heating (about 1100 degrees Cent.) from room temperature to the melting point. This means a linear expansion of $2\frac{2}{3}$ per cent as against the commonly allowed 2 per cent ($\frac{1}{4}$ inch per foot) of the pattern maker. The difference may represent internal shrinkage in practice.

The German investigators do not deal with the coefficient of expansion of the liquid or in detail with the effect of chemical

⁶ Sauerwald and Wecker, *Über die Volumenänderung beim Schmelzen des Roheisens*. Zeitschrift für anorganische und allgemeine Chemie, Vol. 149, p. 273.

composition. In a later paper Sauerwald and Widawski⁷ give further data on the same metals. In the liquid state the densities and specific volumes of Table 4 observed:

Table 4		
<i>Gray Iron</i>		
Temperature Degrees Cent.	Specific Volume	Density
1160	0.1435	6.97
1200	0.1447	6.91
1300	0.1478	6.77
<i>White Iron</i>		
1155	0.1415	7.07
1200	0.1429	7.00
1250	0.1444	6.92

The specific volume is nearly a straight line function of temperature and corresponds closely to

$$v = 0.1415 + 0.000027 (T - 1155) \text{ for white iron}$$

$$v = 0.1435 + 0.000031 (T - 1160) \text{ for gray iron}$$

T being the temperature in Cent. degrees.

It is thus evident that these observers find the coefficient of expansion of liquid iron to be uniform and substantially independent of silicon content, although the density is materially decreased by the presence of silicon. This decrease amounts to 0.0020 in 0.1415 or about 1.4 per cent.

Previous Work on Shrinkage Process

Bardenheuer and Ebbefeld⁸ have published the results of researches on the shrinkage process in gray and white cast iron. By shrinkage they refer to linear contraction, not to the formation of "shrinks" or porous areas. It may be said in abstract, that they find that irons expand at the moment of freezing. This expansion is demonstrated to be due not to the separation of graphite, but to the liberation of gases. It is absent in vacuum melted irons, but may be present in white cast iron. The presence of about 3 per cent or over of silicon prevents such expansion.

⁷ Sauerwald and Widawski, *Über die Dichte und Ausdehnung des weissen und grauen Roheisens im flüssigen und festen Zustande*. Zeitschrift für anorganische und allgemeine Chemie, Vol. 155, p. 1.

⁸ Bardenheuer and Ebbefeld, *Stahl und Eisen*. Vol. 45, Part 22, May 28, 1925, p. 825, and Vol. 45, Part 26, June 25, 1925, p. 1022.

The common elements are shown to affect the total contraction to the degree in which they influence the liberation of carbon between the solidus and the A_1 point. The liberation of carbon, of course, reduces shrinkage, since carbon plus iron occupies more space than an equivalent weight of carbide.

Shrinkage below the pearlite point (700 degrees Cent.) is but little affected by silicon, but increased by the presence of manganese sulphur and to some extent phosphorus in gray iron to a value normal for white cast iron.

It is obvious that within the limits of composition of white cast iron used in the malleable industry shrinkage in the Bardenheuer sense is independent of composition, as we had previously determined. The expansion may be variable as we know nothing as to gas content of the liquid metal.

Relative Tendencies to Porous Spots

The question of the relative tendencies of various commercial heats to shrinkage, in the sense of porous spots, has so far eluded all direct quantitative systematic observation.

What is required is some means of determining by fairly simple methods the characteristics of metal made under commercial conditions.

Investigational Considerations

Upon reflection the following conclusions were reached: Internal shrinkage represents the changes of volume of the interior of a casting during cooling (largely during freezing) after the exterior has solidified. If, therefore, an object can be designed whose outer walls will not collapse under atmospheric pressure as the interior shrinks, then shrinkage will be represented by voids in the casting.

The above conclusion is true only if no feeding, positive or negative, takes place.

It is not important to know the dimensions of the mold, for these can be calculated if required from the dimensions of the casting and the constant, known linear contraction. The correction is in any event a numerical constant and may be neglected in the interests of simplicity if metals are merely to be compared.

The body least likely to collapse is a sphere. The smaller it is, the more rigid, but it must be large enough to permit of

density determinations of much higher precision than the variations in density produced by varying voids due to shrinkage.

The greatest percentage of accuracy in weighing with the equipment available in this laboratory is on a mass of 1 kilogram which can be weighed to 0.1 milligram. Smaller spheres can be weighed to the same or slightly greater precision but the percentage is decreased due to the smaller load and the balances available for weighing in excess of 1 kilogram do not weigh with such great precision.

A sphere $2\frac{1}{2}$ inches in diameter, pattern size, not fed, weighs about 1.04 kilograms and this body was regarded as suitable for trial. The body should be bottom poured and vented at the top to minimize danger from air bubbles or slag inclusions. The gate into the casting should be small enough to freeze promptly but not so small as to prevent quick pouring of the casting. A minimum diameter of 0.25 inch was arbitrarily selected. The runner should be only large enough to deliver the iron to reduce danger of the casting feeding the runner before the gate freezes and to still further reduce this danger the pouring sprue should be fairly large and high so that it will feed the runner if necessary. Further, it is desirable to have several test bodies poured at once to permit taking an average of several concordant determinations or the exclusion of defective test bodies.

Test Methods Followed

The pattern decided upon is shown in Fig. 4. Molds are to be of dry sand.

As a trial two molds were poured from the beginning and end of a heat. The densities of the test bodies were determined, as well as the density of solid metal from the top of the runner. The results are tabulated below in Table 5, densities being at about $17\frac{1}{2}$ degrees Cent. and expressed in gms./cm³.

Table 5

	Poured Hot	Poured Cold
Densities of four test bodies...	$\left\{ \begin{array}{l} 7.5905 \\ 7.5907 \\ 7.5890 \\ 7.5817 \end{array} \right.$	$\left\{ \begin{array}{l} 7.6112 \\ 7.6090 \\ 7.6056 \\ 7.6280 \end{array} \right.$
Mean density	7.5875	7.6135
Density of solid metal.....	7.7167	7.7112
Per cent voids	1.67	1.30

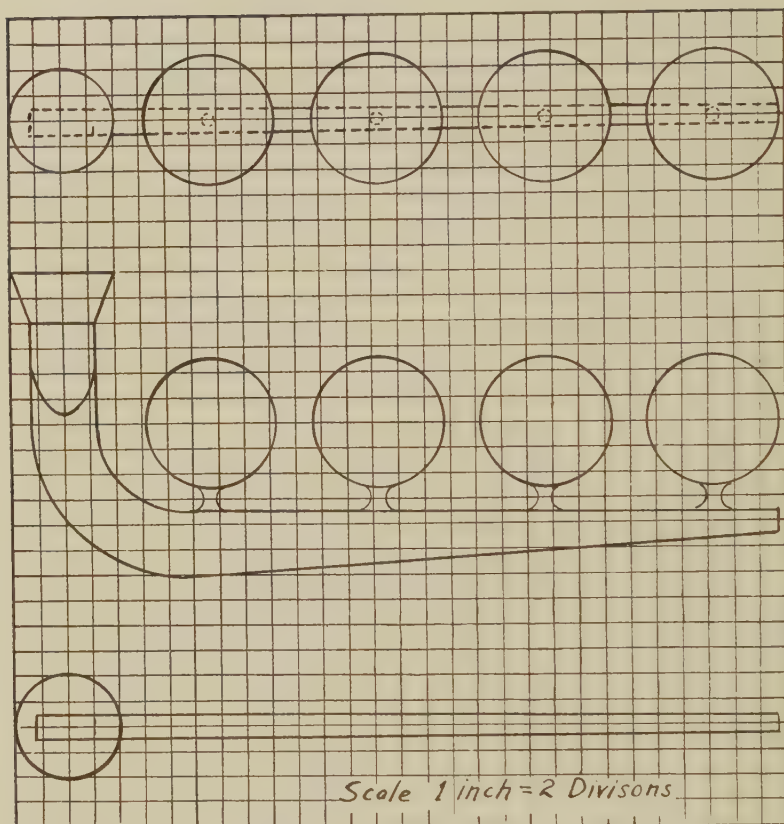


FIG. 4—TEST SPECIMENS (ON GATE) USED IN MEASURING THE SHRINKAGE TENDENCY OF WHITE CAST IRON

The density of solid metal should, of course, be the same in both cases, the difference being of the order of 0.1 per cent and insufficient to affect the percentage of voids. It is believed that the agreement of densities of the four bodies poured together is such as to warrant confidence at least in the uniformity of results obtained and that the difference observed between hot and cold metal indicates the method to be of promising sensitivity. Incidentally, it also points to the need of precise pouring temperature.

T. M. Chapman next made five heats for study by this method and H. H. Johnson made the requisite density measurements.

The first heat was intended to be silicon free and the results of Table 6 were obtained.

Table 6

— Analysis —		Metal Temp.	Density of Ball	Density, if Solid	Per Cent Voids	Mark
C.	Si.					
2.23	.09	Cold	7.2968	7.4964	2.663	A 1
2.23	.09	Cold	6.8751	7.4964	8.288	A 2
2.23	.09	Cold	7.1342	7.4964	4.832	A-3
2.23	.09	Cold	7.3330	7.4964	2.180	A 1 Evac.
2.23	.09	Cold	6.9644	7.4964	7.097	A 2 Evac.
2.23	.09	Cold	7.1547	7.4964	4.558	A 3 Evac.

These balls were obviously full of pin holes. They were weighed, first in air, then in water, and then were evacuated and reweighed in water. The first three results are without evacuation, the last three with evacuation.

It is doubtful just how we should interpret the results of gassy irons such as this. The gas pockets, of course, do represent a difference in volume between the liquid and solid as in our other measurements. Whether the gas evolved at a time when an equivalent volume of metal could be forced back through the gate or whether the pressure is sufficient to expand the outer shell after freezing, we do not know. Either of these phenomena would interfere with the principle of the experiment.

The next four heats of a nearly constant and rather low silicon content gave but little trouble from gassing. The results are tabulated in Table 7.

It will be seen that the results are reasonably concordant in each group of balls except perhaps the surprisingly great soundness of two of the cold poured balls containing 2.53 carbon. The 2.94 carbon balls showed a very slight mottle which, if it did not exist in the small density specimen, is roughly estimated to be equivalent in effect on density to about 0.2 per cent of voids.

The hot poured high carbon balls showed a considerable settle near the top, estimated at perhaps 0.5 per cent of the volume of the ball. There was thus some liquid contraction before any rigid shell formed and the true percentage of voids should have been greater by this amount which, roughly, balances the effect of graphite.

Table 7

Analysis		Metal Temp.	Density of Ball	Density, if Solid	Per Cent Voids	Ave. Per Cent Voids
C.	Si.					
1.60	.67	Hot	7.5386	7.7635	2.897	2.232
1.60	.67	Hot	7.6299	7.7635	1.721	
1.60	.67	Hot	7.6023	7.7635	2.077	
2.35	.69	2785° F.	7.6151	7.7414	1.632	1.634
2.35	.69	2785° F.	7.6045	7.7414	1.769	
2.35	.69	2785° F.	7.6223	7.7414	1.538	
2.35	.69	2785° F.	7.6177	7.7414	1.598	
2.35	.69	2500° F., approx.	7.6108	7.7440	1.720	1.717
2.35	.69	2500° F., approx.	7.6184	7.7440	1.622	
2.35	.69	2500° F., approx.	7.6058	7.7440	1.785	
2.35	.69	2500° F., approx.	7.6091	7.7440	1.742	
2.53	.65	2900° F.	7.6309	7.7434	1.453	1.413
2.53	.65	2900° F.	7.6324	7.7434	1.433	
2.53	.65	2900° F.	7.6308	7.7434	1.454	
2.53	.65	2900° F.	7.6419	7.7434	1.311	
2.53	.65	2600° F., approx.	7.6992	7.7443	0.582	1.013
2.53	.65	2600° F., approx.	7.6700	7.7443	0.959	
2.53	.65	2600° F., approx.	7.6419	7.7443	1.322	
2.53	.65	2600° F., approx.	7.6522	7.7443	1.190	
2.94	.55	2725° F.	7.5971	7.7274	1.685	1.702
2.94	.55	2725° F.	7.5953	7.7274	1.710	
2.94	.55	2725° F.	7.5992	7.7274	1.659	
2.94	.55	2725° F.	7.5919	7.7274	1.753	
2.94	.55	2500° F., approx.	7.6021	7.7254	1.596	1.590
2.94	.55	2500° F., approx.	7.6103	7.7254	1.490	
2.94	.55	2500° F., approx.	7.5976	7.7254	1.654	
2.94	.55	2500° F., approx.	7.6002	7.7254	1.620	

We cannot, of course, draw general conclusions from such meager data as here recorded, especially not until we know more of what other variables affect the results. So far as the figures are reliable they show 2.50 per cent carbon metal to be less prone to shrink than either a higher or lower carbon product. Cold pouring still seems generally favorable to sound castings.

Investigation to Ascertain True Density

G. M. Guiler undertook an investigation in order to ascertain whether it is necessary to determine the true density each time or whether this may be calculated from the chemical composition. The writer's published figures for the density of hard iron have already been referred to.

It was known that silicon reduces the density of ferrite, probably by substituting for Fe atoms in the α lattice.

Since Mn, of nearly the same atomic weight of iron, enters into a substitutional position in the lattice and is not very variable in concentration in ordinary malleable, its effect on density was deemed negligible. Phosphorus and sulphur were neglected as

nearly constant, although the latter as MnS no doubt decreases the density by a readily calculable amount.

Effects of Carbon and Silicon

Guiler's experiments concerned themselves solely with the effects of carbon and silicon. Specimens in the form of unannealed A. S. T. M. bars were obtained from each of the company's malleable plants to the number of twenty-five heats in all. They were selected as differing considerably in silicon without differing unduly in carbon content. Three specimens were broken from the gauge length of each bar, carefully cleaned and the specific volume determined at a room temperature of about 27 degrees Cent. on the basis of weighing in air with brass weights. The results are given in Table 8.

Table 8

Plant	C., Per Cent	Si., Per Cent	Specific Volume	Mean Spec. Vol.
A	2.40	.66	.12934-.12931-.12936	.12933
A	2.62	1.01	.13000-.13000-.12996	.12998
A	2.59	.85	.12971-.12983-.12975	.12976
A	2.62	.77	.12957-.12962-.12957	.12958
B	2.54	.82	.12946-.12945-.12947	.12946
B	2.50	1.10	.12957-.12964-.12964	.12954
B	2.50	.95	.12943-.12958-.12962	.12954
B	2.50	.98	.12968-.12962-.12964	.12964
C	2.63	.74	.12956-.12956-.12959	.12957
C	2.48	.85	.12978-.12962-.12999	.12979
C	2.48	1.01	.12992-.12992-.12993	.12992
C	2.36	1.17	.12996-.12996-.13004	.12998
D	2.72	.98	.12995-.12992-.12984	.12990
D	2.58	.77	.12962-.12984-.12969	.12971
D	2.57	.84	.12988-.12983-.12985	.12985
D	2.62	.90	.12977-.12985-.12975	.12979
D	2.58	.95	.13019-.12986-.12990	.12998
E	2.54	1.07	.12990-.12988-.12985	.12987
E	2.52	.90	.12963-.12973	.12966
E	2.69	.83	.12984-.12974-.12978	.12978
E	2.59	.95	.12972-.12974-.12972	.12972
E	2.59	.80	.12958-.12954-.12953	.12955
E	2.59	.80	.12947-.12956-.12955	.12952
E	2.53	.70	.12942-.12939-.12937	.12939
E	2.58	.65	.12947-.12946-.12941	.12944

Probable Error

The probable error of a single specific volume determination, comparing each with the average of all determinations on the same material, was found to be 0.000038 and hence the probable

error of the mean values is $\frac{1}{\sqrt{3}}$ times this amount or about 0.00002. The error of a single determination is thus of the order of magnitude of $\frac{4}{13000} = 0.035$ per cent.

We may calculate the probable error due to weighing errors in the determination of density. Assuming a probable error of 0.1 milligram in any weighing, the probable error in the difference of the weights in water and air is $0.1 \times \sqrt{2} \text{ mg} = 0.14 \text{ mg}$.

The specific volume being the weight of displaced water, probable error 4.14 milligram; divided by the weight in air, probable error 0.1 milligram can have its probable error calculated, remembering that the latter figure is about 7.5 times the former from formula (29) Merriman's Method of Least Squares^a, which reads

$$R_2 = z_1^2 r_2^2 + z_2^2 r_1^2$$

when R is the probable error of the product of z_1 and z_2 which have probable errors of r_1 and r_2 respectively.

In our problem let z_1 be the weight of water displaced and z_2 be the reciprocal of the weight in air. If the former be of the order of 2 grams the latter will be about 1/15 gm. The error of weighing in the former is 0.007 per cent, in the latter 0.0007 per cent, and we may write

$$R^2 = (.007 \times 2)^2 + (.0007 \times .07)^2.$$

Very obviously the second term vanishes in comparison with the first, being only 1/900000 of that value and due to errors of weighing alone the probable error of a single specific volume determination is less than 0.01 per cent, i. e., about $\frac{1}{3}$ the observed probable error. Of course, other observational errors exist, for example, in the measurement of the temperature and hence density of the water. An error of 1 degree Cent. would involve here an error of about 0.03 per cent; the coefficient of expansion of iron is small but would involve some error.

The largest source of error is probably the lack of absolute soundness of test specimens. This produces only high values of specific volume, never low ones; that is, the error is always in one direction. If this be the predominant source of error then the lowest specific volume obtained on any specimen is the most probable. The mean value of the lowest specific volume for each

^a Merriman, *Method of Least Squares*, page 78.

specimen is 0.129652 as compared with 0.129692 as the mean value of the average. If this correction be justifiable, then the true specific volume is 0.00004 less than any calculated from the average values.

Effect of Carbon and Silicon on Specific Volume

With a view to deriving a formulæ for the effect of carbon and silicon on specific volumes we may proceed as follows: Assuming the density of iron to be 7.87 and of Fe_3C to be 7.45, the results being a rough average of the available determinations in each case, we find

$$\text{Spec. Vol. Fe} = \frac{1}{7.87} = 0.127065$$

$$\text{Spec. Vol. Fe}_3\text{C} = \frac{1}{7.45} = 0.134228$$

If $C = \% C$ in a given metal the per cent of Fe_3C is $\frac{180}{12} C$ or $15 C$.

Then by the principle of mixtures:

$$\begin{aligned} \text{Spec. Vol.} &= \frac{(100 - 15C) \times 0.127065 + 15C \times 0.134228}{100} \\ &= 0.127065 + 0.001074C \end{aligned} \quad (1)$$

From (1) and the carbon content of the several specimens we may calculate their theoretical density in the absence of silicon as shown in Table 9 and determine the difference between the calculated and observed values.

Table 9				
C.	Si.	Calculated	Observed	Calc.-Obs.
2.40	.66	.12964	.12934	30
2.62	1.01	.12988	.12999	-11
2.59	.85	.12985	.12976	9
2.62	.77	.12988	.12959	29
2.54	.82	.12979	.12946	33
2.50	1.10	.12975	.12962	13
2.50	.95	.12975	.12954	21
2.50	.98	.12975	.12965	10
2.63	.74	.12989	.12957	32
2.48	.85	.12973	.12980	-7
2.48	1.01	.12973	.12992	-19
2.36	1.17	.12960	.12999	-39
2.72	...	.12999	.12990	9
2.58	.77	.12984	.12972	12
2.57	.84	.12983	.12985	-2
2.62	.90	.12988	.12979	9
2.58	.95	.12998	.12998	-4
2.54	1.07	.12979	.12987	-8
2.52	.90	.12977	.12968	9
2.69	.83	.12995	.12979	16
2.59	.85	.12985	.12973	12
2.59	.80	.12985	.12955	30
2.59	.80	.12985	.12953	32
2.53	.70	.12978	.12939	39
2.58	.65	.12984	.12945	39

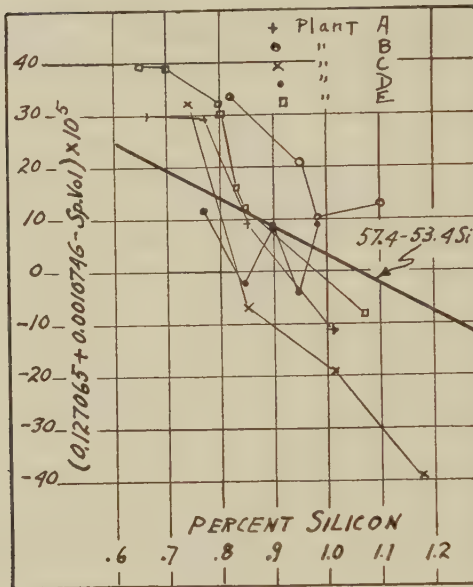


FIG. 5
DENSITY OF WHITE CAST IRON AS A FUNCTION OF COMPOSITION

The differences are plotted against silicon content in Fig. 5. It is evident that they decrease, algebraically, as the silicon increases. The rate of decrease is not alike in all plants, being very small in the case of Plant D, and largest in the case of plant C.

The mean relationship was calculated by the method of least squares and found to be:

$$e = 0.000574 - 0.000534 \text{ Si} \quad (2)$$

where e is the calculated value minus the mean observed value of specific volume. We may then combine (1) and (2) and write

$$\begin{aligned} \text{Sp. Vol.} &= 0.127065 + 0.001074 \text{ C} - 0.000574 + 0.000534 \text{ Si} \\ &= 0.126491 + 0.001074 \text{ C} + 0.000534 \text{ Si} \quad (3) \end{aligned}$$

The probable error of a single average value compared with this formula was found to be 0.000095 or about five times the probable error of that average value. The probable error of the

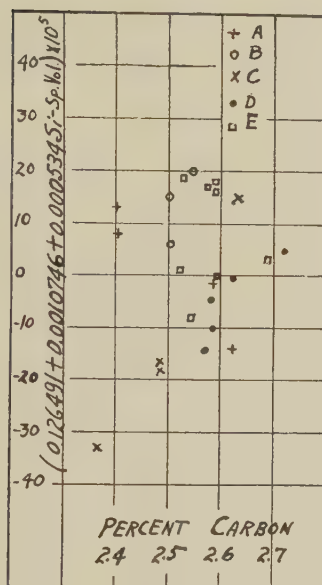


FIG. 6
DENSITY OF WHITE CAST IRON AS A FUNCTION OF COMPOSITION

formula as compared with the average of all average values is

$$\frac{1}{\sqrt{24}}$$

or say 1/5 of the above, so that it may be said that the formula will average as good an agreement with the truth as will a single specific volume determination.

In Fig. 6 the difference between the calculated value by formula (3) and the observed value is plotted against carbon content. For plant A the resulting line falls with increasing carbon, for plants C and D it rises, and plants B and E show no particular direction. It thus seems unlikely that any further correction for the effect of carbon is called for and our assumptions as to the derivation of (1) are justified.

Variation in Different Plants

It is, however, obvious that the different plants arrange them-

selves on somewhat different levels in this figure. The average ordinate for the several plants is as follows:

Table 10

A	0.00001
B	0.00014
C	0.00014
D	0.00005
E	0.00008

The mean specific volumes are therefore different at the several plants which may point to a variation in soundness of test bars in proportion to the figures in the above table. Arbitrary corrections of these amounts would reduce the probable errors by about one-fourth of the amounts just given.

For the purposes of the major investigation we may leave the subject with the concept that the formula is about as good a guide to the density of a given metal as is a single density determination. Either is exact to well beyond 0.1 per cent, which is much better than we can expect for the agreement of the shrinkage experiment.

In Table 11 are given the results of such tests on a series of commercial heats.

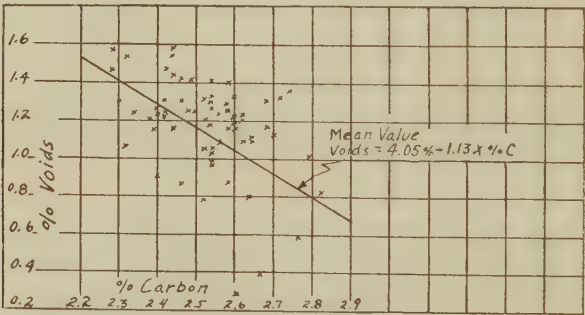


FIG. 7

CARBON CONTENT IN RELATION TO SHRINKAGE OF WHITE CAST IRON

The data for the week commencing 1-9-28 in each table were obtained without the precaution of subjecting the sample immersed in water to a vacuum and hence include as voids small surface pores, from which the air may not have escaped, hence the greater density.

Table 11

Date	Furnace and Heat	Apparent Density	Calculated Spec. Vol.	Per Cent Voids
1-9-28	1—1	7.5966	.129963	1.27
	1—2	7.5916	.129431	1.74
	3—1	7.6115	.129618	1.34
	3—2	7.6123	.129597	1.35
1-10-28	1—1	7.5748	.129761	1.61
	1—2	7.5715	.129855	1.68
	3—1	7.6313	.129608	1.09
	3—2	7.5978	.129742	1.42
1-11-28	1—1	7.5495	.129817	1.99
	1—2	7.6004	.129705	1.42
	3—1	7.5966	.129640	1.52
	3—2	7.6063	.129726	1.33
1-12-28	1—1	7.6010	.129785	1.35
	1—2	7.6087	.129753	1.37
	2—1	7.5889	.129630	1.63
	3—2	7.5910	.129839	1.44
1-13-28	1—1	7.5724	.129764	1.74
	1—2	7.6019	.129640	1.45
	3—1	7.6062	.129560	1.45
	3—2	7.5456	.129700	2.14
1-14-28	1—1	7.5868	.129860	1.48
	1—2	7.5847	.129785	1.56
	3—1	7.6001	.129732	1.40
	3—2	7.5748	.129700	1.74
1-16-28	1—1	7.6253	.129565	1.21
	1—2	7.6340	.129469	1.16
	3—1	7.5944	.129646	1.55
	3—2	7.6031	.129592	1.47
1-17-28	1—1	7.6067	.129757	1.30
	1—2	7.6043	.129640	1.42
	3—1	7.5940	.129608	1.58
	3—2	7.6101	.129812	1.22
1-18-28	1—1	7.6161	.129592	1.30
	1—2	7.6495	.129710	.78
	3—1	7.6399	.129855	.80
1-19-28	1—1	7.6116	.129865	1.16
	1—2	7.6114	.129716	1.27
	3—1	7.6041	.129667	1.40
	3—2	7.6118	.129785	1.22
1-20-28	1—1	7.6171	.129672	1.23
	1—2	7.6211	.129608	1.23
	3—1	7.6112	.129458	1.47
	3—2	7.6186	.129753	1.15
1-21-28	1—1	7.6216	.129774	1.09
	1—2	7.6331	.129726	.98
	3—1	7.6191	.129716	1.17
	3—2	7.6068	.129716	1.33
1-23-28	1—1	7.6004	.129565	1.53
	1—2	7.6226	.129716	1.13
	3—1	7.6153	.129737	1.20
	3—2	7.6071	.129732	1.31
1-24-28	1—1	7.6180	.129645	1.24
	1—2	7.6145	.129699	1.24
	3—1	7.6157	.129866	1.10
	3—2	7.5909	.129946	1.36

(Concluded on next page)

Table 11—(Continued)

Date	Furnace and Heat	Apparent Density	Calculated Spec. Vol.	Per Cent Voids
1-25-28	1—1	7.6104	.129807	1.21
	1—2	7.6264	.129501	1.24
	3—1	7.6105	.129866	1.17
	3—2	7.6037	.129684	1.41
1-26-28	1—1	7.6075	.129817	1.24
	1—2	7.6084	.129791	1.25
	3—1	7.6128	.129893	1.12
	3—2	7.5963	.129893	1.33
1-27-28	1—1	7.6080	.129740	1.29
	1—2	7.6047	.129619	1.43
	3—1	7.6186	.129834	1.09
1-28-28	1—1	7.6145	.129898	1.09
	1—2	7.6186	.129603	1.26
	3—1	7.5987	.129769	1.39
	3—2	7.5981	.129764	1.40
1-30-28	1—1	7.5989	.129527	1.57
	1—2	7.6220	.129495	1.30
	3—1	7.5990	.129887	1.30
	3—2	7.6020	.129689	1.41
1-31-28	1—1	7.6479	.129614	.87
	1—2	7.6253	.129618	1.16
	3—1	7.6120	.130048	1.01
	3—2	7.6330	.129758	.96
2-1-28	1—1	7.6101	.129704	1.30
	1—2	7.6394	.129769	.87
	3—1	7.6820	.129807	.28
	3—2	7.6260	.130054	.82
2-2-28	1—1	7.6088	.129715	1.30
	1—2	7.6117	.129817	1.19
	3—1	7.6480	.129995	.58
	3—2	7.6150	.129678	1.25
2-3-28	1—1	7.6281	.129721	1.05
	1—2	7.6157	.129791	1.16
	3—1	7.6710	.129855	.39
	3—2	7.6500	.129533	.91
2-4-28	1—1	7.6289	.129699	1.05
	1—2	7.6243	.129796	1.04
	3—1	7.6040	.129759	1.33
	3—2	7.6700	.129656	.55

Some of the balls showed the effect of settling as dimples in the surface. Supposedly, such dimpling forms part of the fluid contraction of the ball. The number of dimples in the week of 1-9-28 were not recorded.

In Fig. 7 is plotted the percentage of voids for all heats made during the last three weeks of that investigation against carbon content.

Note:—Extrapolation seems to show the disappearance of all voids near 3.6 per cent carbon or in the neighborhood of the eutectic ratio allowing for the effect of silicon.

The results are quite scattering, the percentage of voids varying by perhaps $\frac{1}{2}$ per cent (40 per cent of the mean value) for a given carbon content. There appears, however, to be a tendency for a decrease in voids with increasing carbon.

Concluding Observations

With the view to obtain greater certainty of interpretation than is possible graphically the relation between carbon, silicon and shrinkage has been analyzed by the method of least squares, and the following formula obtained

$$S = .398C + 1.22Si - .933$$

where S, C and Si represent respectively the percentages of voids of carbon and of silicon. It will be noted that a rigid mathematical analysis shows the shrinkage to increase with increase in carbon and silicon. The negative numerical term which theoretically should be equal to the percentage of voids in a casting of pure iron can have no physical meaning, for in the sense of the present experiment there can be no such thing as negative shrinkage. Even a metal, which expanded on freezing, remaining perfectly solid would obviously not give a negative value under the experimental conditions. It is, therefore, quite evident that although the formula agrees empirically with the data as well as any straight line relations can, it still contains some sources of error either experimentally or of interpretation.

Attention must be invited to a further anomaly. The percentage of shrinkage in the heats in question agrees with the numerical average of all the shrinkage determinations with a probable error of approximately 0.20. The observations agree with the values calculated from the formula involving carbon and silicon content with a probable error of 0.21. It appears, therefore, that the variations due to carbon and silicon content are negligible in comparison with the variations due to other causes and it, therefore, appears that the solution of the problem of reducing shrinkage of white cast iron primarily lies along lines other than carbon and silicon control.

It is to be clearly understood that the last statement applies strictly within the limitations of the present experimental conditions and must not be in anywise interpreted as having a bearing

on which metal will feed most efficiently. The latter question is beyond the scope of the problem which the writer had set himself for discussion. At this time it is not the intention either to confirm or deny the frequently accepted theory that high carbon metal requires smaller feeders than low carbon metal.

It is hoped, however, that the work on shrinkage here recorded, even though not yet giving absolutely accurate results, will have some value as furnishing a starting point for the gathering of evidence by others which in the course of time may largely clarify our understanding of the entire subject.

One suggestion may be made to any others who contemplate working by the method here described. Experience in operating the method has pointed toward the desirability for somewhat smaller balls, this in order to reduce the danger of the formation of primary graphite and also to permit easier weighing. Were we to start over again we would probably adopt a ball weighing about 500 grams instead of the size which has been used so far. The remainder of the experimental procedure has thoroughly justified itself in use.

Materials Handling in Gray Iron Foundries

BY ALBERT WALTON,* PHILADELPHIA, PA.

The difference between economical handling of materials in foundries and an unsystematic method, often establishes the reason for a profit in the first case and a loss in the second. In this paper it is our intention to extend possibly the ordinary conception as to what is meant by "handling materials" and to cover under this caption, handling processes of every kind from unloading pig iron, etc., when received in railroad cars at the foundry yard, to the shipping of finished castings and the disposal of refuse, and dust; including between these two extremes, handling of every character whatsoever, connected with the manufacture of castings.

Materials Handling Operations

To attempt to establish a standard method of handling materials is practically impossible. There are modern, partly modernized and old type foundries by the hundreds scattered throughout the country. Modern foundries, and by this term is meant those built to modern engineering design, can be considered fairly uniform and conform to standardized practices as understood today. In so far as they differ in size, and in class of work that is intended to make, they can be considered as being built with

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Discussion of this paper begins on page 603.

the expectation of including therein all modern facilities for the following operations:

1. Unloading raw materials.
2. Stocking same in yards and bins.
3. Rehandling from yards and bins to cupola charging floor and to cupola.
4. Rehandling from yards and bins to molding and core rooms.
5. Receiving and storing, in suitable stock rooms, all necessary materials and supplies, repair parts, etc., required in conducting operations, and not stored in bulk in yards and bins.
6. Necessary facilities for withdrawing from such store rooms and delivering to the place at which needed, the various commodities kept therein.
7. Handling of molds from molder to pouring floor by suitable conveying tables, etc.
8. Handling of molten metal to molding and pouring floors.
9. Handling of molding and core sand to their respective floors.
10. Shake out of flasks and removal of castings, scrap and sand.
11. Delivery of castings to cleaning room and to tumbling barrels and sand blast machinery, etc.
12. Removal of castings from cleaning room to inspection department and to manufacturing and shipping department.
13. Removal of dust from cleaning rooms and from tumbling barrels and sand blast equipment.
14. Conveying of foundry sand to sand removing and bonding equipment and subsequent delivery of foundry molding sand to hoppers and bins.
15. Handling of flasks from storage to foundry and return.
16. Handling of patterns from storage to foundry and return.
17. Handling of cores from core room to foundry and return.

These various handling operations will, of course, differ in

each foundry. The physical arrangement of the yard and buildings, the type of foundry, whether or not it is to be used for making light or heavy work or for a combination of the two, will all have a vital effect on just what type of handling equipment should be used to produce the best results.

Factors to Be Studied

In the installation of labor saving equipment for handling purposes, careful study has to be made covering the factors of cost in connection with all cases where such equipment is under consideration. The factors listed below should be considered or worked out, the estimated results being conservatively figured:

A. Present labor cost of doing work over a reasonable period of time. One month would be a fair average when foundry is running on normal output.

B. Maintenance, repair and other overhead expense for equipment at present used, established for the same period.

C. Cost of present method of handling, for such materials as it is contemplated handling by installation of improved mechanical devices.

D. Estimated cost of new equipment, etc., including installation.

E. Maintenance and repair thereof, including fair charge for depreciation and other general expenses.

F. Labor cost to operate new equipment, for same time and under same conditions, as item "A."

G. Total cost of proposed new method of handling.

H. Salvage value, if any, of equipment to be discarded when new method is installed.

I. Saving to be effected by adoption of new plan, analyzed as follows:

1. Reduction in payroll for labor.
2. Reduction in other operative charges.
3. Elapsed time saved for handling equivalent tonnage.
4. Increase or decrease in maintenance, repair, power, depreciation and other expense charges, including interest on money invested in new equipment installed.

5. Net saving in dollars for given period.
6. Increase in time saved and in tonnage handled per hour, and per man.
7. Length of time it will take to make the necessary changes.
8. Length of time it will take to pay for the net value of new equipment including installation expense.

You cannot go into too much detail in estimating what will be the cost of, and the savings to be effected, through the installation of handling devices of any kind.

Some Applications of Lifting Magnets

Concrete examples can be quoted for savings made through installation of many kinds of equipment, such as are covered in the preceding review.

It may be interesting to note a number of actual economies that have followed the installation of different classes and types of handling equipment, and the figures which will be quoted are all a matter of record. Some applications of lifting magnets and their use are as follows:

A. Unloading of pig iron and scrap from railroad cars and stocking same in yard.

B. Handling pig iron and scrap to cupola charging boxes and buckets.

C. Direct cupola charging by magnet, in this method of charging cupola, if the operation is continuous for a number of hours, it is advisable to use two magnets as relief to each other, due to cupola heating effect, this change, however, does not have to be made oftener than every $1\frac{1}{2}$ to 2 hours.

D. Distribution and return of iron flasks to and from molding floors.

E. Used for lifting iron or steel copes, picking up and transferring castings to cleaning room or to suitable trucks, going over molding floors after castings are removed and picking up gates, risers, nails and other pieces of iron and steel, requiring an oblong magnet to cover wider area; with systematic use of lifting magnets inside foundries, a reduction in labor cost connected with

the handling of the operations just described, can be made to an extent that may easily reduce the cost of labor to 1/10 what it would be without mechanical appliances.

F. To figure a saving in any foundry is only a detail and allowing for maintenance charges for crane and magnet service, depreciation on such equipment, crane operator and floor operator, two men only, such an installation will replace 10 or 12 men, and do the work more effectively and quicker and will stack flasks or pile castings to any reasonable height below crane runways thus economizing in space, as well as enabling this work to be started while the castings are still hot, all that is necessary being to wait until the hot castings are cooled sufficiently for the induction of magnetic properties, which will take place while the castings are a dull red.

G. Again, lifting magnets can be used in transferring molding sand around foundry floor, provided the receptacles used are iron or steel boxes or buckets. The prime advantage in inside use of lifting magnets is due to the elimination of the labor necessary to place sling chains around loads and the time it takes to do this, especially on heavy work. When we realize that lifting magnets can be installed with weight lifting capacities from a few hundred pounds to as high as 65,000 pounds, the advantage of their use becomes apparent.

H. The wiring of yard and interior cranes for facilities in using lifting magnets is, of course, necessary and after that the magnets can be moved from one crane to another. The economy and speed at which skull crackers can be operated and the elimination of the need for handling floor sand to screens for removal of iron scrap, nails, etc., are both worthy of consideration.

In addition to using the lifting magnet with overhead electric traveling cranes, they can also be used with any good type of tractor cranes. They can also be used with such tractor cranes of which there are several makes well adapted for use around foundry yards as well as inside the foundry. Cranes of this type have proven equal to handling pig and scrap at one-tenth the cost of hand labor.

Portable Crane with Single Line Bucket

A report from a user of a portable crane, equipped with single line grab bucket, used for handling all refuse, slag, unloading of sand and coke in yard, digging of pits, and the filling up of drag flasks with backing sand, in fact, in use practically 24 hours per day, was to the effect that it has saved this foundry the labor of 8 to 10 men every working day and increased efficiency due to being able to handle floors immediately after shake out while castings and sand, etc., were still hot.

It also increases molders earnings, and more important still, production, through keeping floor cleaned up, and maintaining better and more continuous supplies of sand and facings and eliminating the delays that molders under previous method had to endure.

You may not realize it, but such a machine, with its work properly scheduled, can care for a large variety of work, and the maintenance cost is low, if kept up in proper shape and inspected daily for signs of wear, need of lubrication, etc.

These single line buckets, with tractor truck, can be used for economically cutting over and mixing molding sand, a record of 35 minutes being reported for working a sand heap 80 feet long, 4 feet high and 5 feet wide, thoroughly cut and mixed ready for the molder, labor required, one crane tractor operator and one laborer. Compare this with the cost of doing the same work under hand shovel methods.

Again, a 60 ton car of sand can be unloaded in an hour with a bucket of this type with the labor of the crane operator and one laborer. Also railroad cars can be switched in your own yards with ease.

Another advantage in some shops and yards, for this type of crane is due to its flexibility of movement and as a rule enough uses can be found for a tractor crane of two tons capacity to keep one steadily employed practically full working hours inside and outside the foundry. This is where the economy comes in on all equipment of this nature. If it is used only 10 per cent or thereabouts of the total working hours, its economy becomes a

doubtful factor, but where it can be used the greater part of the time, the reduction in cost and advantage of increased production over hand labor becomes very marked. With well laid concrete floors around yards and in the foundry, those inside the foundry being laid with due regard to molder's floor areas, which should never be concreted, a large amount of work can be done with a tractor crane that for some classes of work is preferable to the use of an overhead traveling crane. In fact, in the old style foundries, it is often impossible to install satisfactory overhead crane service and in such shops, the use of the tractor crane is invaluable.

Tractor Trucks

Tractor truck equipment of any kind has to meet severe service in foundry work due to uneven floors, abrasive action of foundry dust and sand and damage to tires from sharp pieces of metal. For these reasons it is obligatory that runways be properly constructed as previously mentioned, of concrete or other paving and that they be kept clean. It is to be also noted that the proper conditioning of gangways, etc., has a wholesome effect on foundry help. If the foundry and yards are kept clean, and everything is piled in systematic shape, such conditions will have a psychological effect on the workers themselves and will be beneficial in many ways.

A record furnished by a foundry shows that a truck of this type used for charging annealing ovens reduced the cost below the prior method of hand truck charging as follows:

"With hand trucks, 6 men were employed $4\frac{1}{2}$ hours to charge one oven. The annual payroll for work done by these 6 men was \$5,670.00 or \$18.90 per day or 84 cents per ton of iron castings. Using an electric truck the saving in the annual payroll was \$2,881.23 or \$9.60 per day or 42.6 cents per ton of iron castings, this saving paying for the electric truck installation in about 15 months. The life of such a truck, properly looked after, being at least 8 to 10 years, and the current used in charging the storage batteries at $2\frac{1}{4}$ cents per kilowatt hour amounts to \$48.60 per year."

Machine Charging Cupolas

At this point it may be of value to point out the economy of using charging machines for loading cupolas. Their value is very apparent in charging all cupolas where melting tonnage requires the services of over two charging floor laborers.

The labor cost is cut down to practically two men, an operator for the charging device and one laborer on the charging floor.

There are several efficient types of charging machines, using specially designed buckets and centralizing supports in the cupola, that correctly distribute the load of pig iron, scrap, coke and flux over the cupola bed.

Saving One Man's Labor

The saving of one man on a foundry operation can approximately be set at \$1,300.00 to \$2,600.00 per year. This is based upon an average wage rate of 40 cents for a laborer and 75 cents for a skilled man.

In the first case at 40 cents per hour and 3,000 hours per year or \$1,200.00 add 15 per cent to this amount for supervision and you obtain \$1,380.00 per year, which can be considered fairly representative. Where you consider saving a skilled worker at possibly 75 cents, the saving figures \$2,587.50 per year.

You can safely use these figures or factors in figuring the economy to be gained by installing equipment to reduce labor. Then assuming 10 years as the average life of machinery around a foundry when properly maintained, it is easy to figure the possible reduction, after adding depreciation at 10 per cent per year and repairs, supervision, etc., at another 10 per cent per year, then comparing this total with the total of labor eliminated thereby.

You also reduce the liability for human error through carelessness, etc.

Monorails or Tramrails

For foundries having low head room and for others where the molders floors are located in irregular areas, instead of in straight away runs and also where the work made is light in weight, it is often preferable to use monorail or tramrail method of handling.

We have used such installations in both foundry yards for handling pig, scrap, coke, etc., to charging floors, in transferring molten metal from cupola to molders floors and in removing castings, to cleaning rooms and to shop and stock rooms. A well laid out system of tramrails for a foundry where such an installation is applicable, is a sound investment, considerably reducing the labor cost compared with hand labor, wheelbarrow and hand truck movement of materials, sand, castings, etc.

Such equipment will, when properly placed, reduce labor cost at least 75 to 85 per cent.

In fact, the following claims for the productive value of such a handling method are all capable of verifications, viz.—

Moves the same load with fewer men, in fact one or two men can handle loads previously requiring 4 to 6 times the number.

Reduces the labor payroll.

Increases production per unit of time.

Reduces waste in material and damage to product.

Enables floor space to be better utilized.

In pouring off molders floors, a monorail pouring system, with ladle, push button controlled, will enable one man to pour more hot metal in a given time than can be done in the old way by four men.

Economies Produced

When we cite these economies, we wish we could go into details showing the relation between the reduction in labor, increase in production, and the installed cost of modern equipment replacing the labor eliminated, such figures would be too voluminous however, and would differ for practically every foundry. Yet, in practically all handling equipment described herein, the economies resultant therefrom are very gratifying, after allowing for full installation cost, depreciation and interest on the investment. One proviso is to be remembered, however, you do not want to over equip, that is, install equipment considerably in excess of your foundry requirements. We have seen this done with unfortunate results. Any changes contemplated in improv-

ing conditions, must first be carefully worked out on paper and step by step the various important factors established before deciding on the new mechanical units required.

If you can reduce your payroll for handling by ten men, you cut your payroll approximately \$12,000 per year, that is 6 per cent on an investment of \$200,000.00 and such a reduction gives you ample opportunity to install modern equipment at reasonable cost. Also remember, that by so doing you are going to improve conditions throughout your entire plant. Simplicity and ease in handling heavy flasks, in pouring molten metal and subsequently cleaning up the foundry floors, will be reflected in a better satisfied body of workmen, both skilled and unskilled and this again in reduced costs. In fact, in our visits to scores of foundries we have often heard serious criticisms of certain other foundries because they took business at less than cost to the other fellow, and more than once we have had an opportunity later, to find that the low priced foundryman was making money because he had saved it in his various handling operations. He was wide awake and should be commended instead of being condemned and congratulated instead of being censured.

When one visualizes the handling convenience that can be introduced to reduce labor cost, increase production, lessen breakage, etc., it is surprising that there are so many foundries who are not awake to the opportunities confronting them.

How often have you seen in cleaning rooms, lack of facilities for handling and turning over large castings, and need for a simple inexpensive device, lack of which causes twice to three times the labor necessary. Remember that a labor hour rate of 40 cents becomes 80 cents or more per hour when all the general charges are added thereto and at 9 hours per day or \$7.20, 300 days per year figures \$2,160.00. If you can save one man's time, then you have this money to spend on improved facilities. Further multiply this by as many men as you might eliminate after proper study, and you will begin to realize the profits inherent in your business, instead of the losses many of you are sustaining.

We have digressed somewhat from our mechanical story of

modern methods of handling, but we wished you to appreciate just how important a matter it is, and how big a money maker it may become.

Cupola Charging

To return to our review of handling facilities, a few weeks ago we stood on the charging floor of a small foundry and watched two laborers charging a 36-inch cupola. The work was crudely done. The cupola was a small one and the pig and much of the scrap was too large for charging and should have been broken to suitable size. Outside, the piles of pig iron and scrap were dumped at points too far from the cupola and too far from each other. One load of purchased scrap had been dumped along the railroad right of way requiring a long wheelbarrow trip over dirt paths. It required three laborers several hours to bring the metal to the charging floor, in fact, they worked until near time for the blast to go on, then the crude method of charging followed. Much of the iron was dirty and the results showed in the quality of castings produced.

We figured roughly that at common labor rates it was costing the foundry 3 men, four hours each or 12 hours at 40 cents or \$4.80, plus 2 men charging for 3 hours each or 6 hours at 40 cents or \$2.40, total of \$7.20 per day.

Had the metal been prepared and piled adjacent to the cupola, and there was plenty of room, and had a monorail conveyor been installed at slight cost, all the metal could have been placed on the charging floor within one hour by two men. The subsequent charging of the cupola could have been done with less muscular requirement and in a manner that would have given a better bed, with ensuing proper melting and the saving effected would have been in labor alone \$4.00 per day. For 300 days per year, the saving would be \$1,200.00, or enough to have paid for mechanical equipment handling of metal to charging floor and even for a suitable cupola charging device of simple design, that might have eliminated one of the two men employed in charging by hand at an additional saving of \$360.00 per year.

This is indicative of conditions at many smaller foundries.

At more modern foundries of large productive capacity, the benefits accruing from the installations of cupola charging equipment are too well known to require any detail report thereon. We can cite an installation that resulted in the saving of approximately \$4,500.00 per year in handling metal and coke and charging the cupola.

Unloading Material

The cost of unloading coke at this foundry was \$35.00 per car, for 65 cars, or \$2,275.00 per year. This cost was reduced through mechanical methods for unloading to \$1.20 per car, a saving of \$2,197.00 per year. This did not include a direct saving in avoiding the loss of coke through too much handling, which is estimated to be at least 100 tons per year, worth approximately \$700.00. Another saving of approximately \$800.00 per year was gained through being able to have coke shipments received in hopper cars at a saving of 50 cents per ton. Unloading three cars of limestone formerly cost \$35.00 each or \$105.00 per year, and is now being done for \$1.20 per car, a saving of \$102.00 per year. All these cars, with coke, limestone, etc., are being unloaded from a trestle into bins located directly underneath, and the pig and scrap cars by magnet crane, into properly designed bins.

It is surprising how many economies can be brought about by properly installed handling equipment. In this particular foundry, through the improved method of handling, not only were there positive savings in direct handling cost, but a number of indirect savings, such as the reduction of the number of steel plate boxes for handling metal charges, 48 boxes costing \$18.00 per year each for maintenance being reduced to 25 boxes, a saving of upkeep of \$414.00 per year. Also an additional saving was in the use of the yard crane which was cut to one hour daily, where it had formerly been used for two hours per day, at a cost of \$8.00 per hour, making a saving of \$2,400.00 per year.

The net result of all these economies reduced the previous cost of handling materials from railroad cars to bins and then to cupola from \$16,000.00 per year to about \$6,000.00 with a better distribution of the cupola charge and a better controlled molten metal product.

Actual economies acknowledged by users of material handling and cupola charging installations can be given by the score; a few are as follows:

1. Charging an 84-inch cupola with 147 gross tons of metal per day and coke and limestone at \$17.86 per day, or $12\frac{1}{7}$ cents per ton charged.

2. Making up and charging 175 tons per day, one man on charging floor, one on elevator, one on transfer car and four men in yard making up charges, a total for labor of seven men—\$28.00 per day or 16 cents per ton handled.

Other similar instances might be reviewed, all showing sizable reductions in number of men employed under older methods and consequential reductions in cost.

The proper detailing of the various improvements installed in modern foundries cannot be gone into in this paper, but what we are trying to do is to awaken an interest in the minds of many of you as to the possibilities inherent in your business, through the adoption of similar improvements.

Distribution of Molten Metal

The next series of operations following the charging of the cupola covers the distribution of the molten metal.

Here conditions to be met, call for a wide variation in methods of pouring. For large castings, traveling crane transportation of heavy ladles is necessary. In long foundries on smaller work bull ladles carried to specific positions or molding floors are desirable, while hand ladle pouring, taking the metal from the cupola ladle meets all requirements in other cases.

There is a big difference, however, in all these processes between performing the work efficiently and economically and in the less systematic way.

Where crane service is used, positive crane control is necessary to safeguard the pouring of the metal. Ladles with helical worm gearing are preferable where heavy loads are to be handled and where safety requirements call for rigid mechanical specifications. Foundry equipment is more nearly analogous to agri-

cultural equipment, in the severe requirements it has to operate under, than any other equipment of which we know. Always you have to watch out for the abrasive action of dust, sand and other debris and a prime requisite in the specifications for cranes, mechanical ladles, conveyor, tables, etc., is to protect the bearings and provide rigid inspection service.

Conveyor Table Mechanism

Particularly in conveyor table mechanism, it is desirable to see that slides and other wearing surfaces are made of high test iron, with the most efficient wearing factors.

On the foundry floor, conditions vary widely. The modern foundry with systematic and well designed conveying equipment, of link belt or other type, for carrying sand to hoppers above molders' floors, for removing molds to pouring stations and for shaking out, removing castings to cleaning room and sand to renewing and rebonding, apparatus, are all well known. Such installations are, of course, expensive, but with every other facility co-ordinated and buildings, yards, etc., properly laid out, such foundries represent the most economical casting manufacturing units.

We have seen such installations in large automobile plants and in various foundries used for radiator work, etc., and have appreciated the investment required to install them, but on the other hand, we have seen the cost figures for some of them—and the answer is, it paid many times over. It may be confidently stated that such a foundry equipped with complete layout of conveyors, practically doubles its productive capacity per square foot of working area.

Trucking

For the less modern foundry, a great deal can be done to reduce the handling cost inside the foundry. Where trucking of some kind has still to be done, concrete gangways are a decided economy. The use of electric trucks, some with crane attachments, of which there are a number of satisfactory types on the market, can be used to advantage, supplementing flat trucks where used.

Handling Large Tonnage of Small Castings

In foundries producing large tonnages of small castings, suitable box trucks may be used. We have in mind one foundry making hardware castings and miscellaneous small machinery castings, which worked out over a period of years a most efficient method of handling castings through the foundry and then throughout all departments of their manufacturing plant.

This company employed from fifty to seventy-five molders and had in continuous use about two thousand box trucks, each 3'x2'x2' deep, on four wheels. These trucks were made in their own shops. Assorted castings were loaded in these trucks at tumbling barrels and routed through the departments that had to do work on these castings. The system called for one full truck and one empty truck at each operation point. Progress of the work was expeditiously and economically handled. Floors were kept in good condition, being either concrete, wood paving block or hard maple flooring.

Sand Conveying

Sand conveying in the older foundries cannot always be handled as economically as we would wish. Proper location of the sand bins and facilities for conveying new sand into foundry and removing wornout sand, can usually be improved through proper study of the particular problems and the conditions are seldom identical in any two foundries.

Magnet Cranes

After pouring, the shaking out, snagging, separating and removing of castings, gates, etc., can be greatly facilitated through the use of magnet crane and when iron or steel flasks are used, for their reassembly. This was explained in more detail in the earlier part of this paper.

. Location of Cleaning Room

Often there is a problem as to the most economical location for a cleaning room and where space is limited a departure from the ordinary has to be made.

In one foundry with physical limitations in area, a cleaning room was dug beneath the foundry floor. This room was well lighted and ventilated and equipped with three rows of modern tumbling barrels, motor operated. A hatchway opened into the room from the center of the foundry and the delivery of rough castings from each day's heat was greatly simplified. Castings were piled in large plate boxes about 4'x4'x1' deep, lifted by traveling crane and lowered through a hatchway; here after tumbling they were sorted and loaded in trucks, lifted by freight elevator to different floor levels above and started on their passage to manufacturing departments.

In this same foundry, another hatchway opened into a basement room where sand renewing machinery received all worn out sand, treated and renewed same for further use.

These were homemade developments and were economical and labor saving improvements, but how many foundrymen do we have who being limited for space would ever think of going underground for cleaning room and other needs and in such a way that the movement of castings and materials would be greatly simplified and the cost reduced?

Unusual Plans for Reducing Costs

Speaking of unusual plans for reducing cost and securing additional manufacturing space. We recall a foundry in Hamburg, Pennsylvania. It was built at the foot of a steep declivity, the railroad ran on the crest of the rise and the foundry was built back against the hill, so that the charging floor was level with the plane of the railroad track. Pig, scrap, coke and limestone were thus unloaded on the same level as the charging floor and a positive cost-saving factor made out of what otherwise might have been considered a handicap.

We do not think that we have emphasized enough the possibilities of economical and often inexpensive improvements that are possible in many foundries, yet the owners appear at times to be oblivious of the opportunities awaiting development.

For intensive production on a large scale, even in comparatively limited space, there are big possibilities in the installation of sand handling equipment. We would like to review with you the record made by the installation of sand slingers and modern sand handling and conveying equipment in a large automobile foundry. It is too long a story for a paper of this character. Some of these data are available from a report made by the A. C. Nielsen Co. of Chicago.

Suffice it to say, that for a daily average of 85 tons production per day or 23,800 ton per year, the summary figures were as given in Table 1.

Table 1

	Per Year
Savings in labor.....	\$ 57,596.00
Savings in sand handling and conveying.....	35,940.00
Savings in flasks, renewals, etc.	1,745.00
Savings in floor space—9600 sq. ft. utilized, compared with 15,360 sq. ft. formerly required at 60 cents per sq. ft. per year.....	5,856.00
Reduction in scrap—3½% less—833 tons no value established for this factor, but it must have represented—833 tons of good castings at a value representing the difference between scrap at \$14.00 ton and good castings at \$80.00 per ton—or \$49,980.00 worth of good castings added to production that under the old management would have been scrap worth only \$11,660.00 at \$14.00 ton.	
Total gross saving (not including scrap reduction).....	101,137.00
Less fixed charges and operating cost on new equipment.....	19,975.00
Net yearly saving (84.7% on investment)	\$ 81,162.00

Reduction in Molding Costs

We would like to have talked to you about the reduction in molding costs through the use of sand handling devices, etc. In a foundry equipped with modern facilities of this kind, costs were reduced as per typical items as follows:

A—A cast iron side frame, which took a good molder and helper four and one-half hours to ram up with air rammers, is now rammed in sixteen minutes.

B—Boiler sections, formerly made on one type of molding machines at cost of \$1.04 each, are now made with different types of molding equipment for \$0.57 each.

C—Molding labor in man hours per ton of castings has been reduced from 8.1 to 3.6, a saving of 55 per cent in labor production, with the consequent reduction in cost of all other factors affected thereby.

Standardize on Equipment

One important recommendation we make to all of you—always have in mind when you are developing and installing new equipment to standardize all equipment possible. Select cranes, trucks, monorail equipment, ladles, etc., that are standardized for your own plant. You get better service, your workmen have only to familiarize themselves with one type of crane, etc., and this is worth dollars to you, often far in excess of the few dollars to be saved in buying a piece of equipment of different make to another you may have because it is a little cheaper.

Inspection of Equipment

Above all, benefit by the experience of others and employ a man as inspector of machinery and equipment; to daily and continuously inspect all machines, etc., to detect weakness, tendency to failure, etc. It will pay you one hundred fold in reducing repair bills and preventing the shutting down of important mechanical units, that might seriously interfere with your operations. We have for years placed great confidence in having competent mechanics assigned as operating inspectors and always with good results.

Before Equipping Study Conditions

In remodeling or improving your foundry, do not go to extremes. Every foundry is a special study and while you can easily copy the installations of others and spend a large amount of money, you may find that results were not as profitable as they were hoped to be. If you have visions of installing sand handling and treating equipment, remember that you have to take care of the tempering factor in your sand, and have to perform work several times during a day that usually is done over night in a hand foundry. By suitable sand mulling machinery of the mixer type, this can be done properly, the temper and bond being restored to even better effect than in natural tempering.

Again note, that you will usually gain by adhering to standard and proven mechanical methods for many handling processes.

Of course, we are not hide bound and we realize that progress continues day by day.

Mechanical Handling Saves Space

It is one of the advantages of mechanical methods of handling that substantial savings in working space can be obtained. We might say that this saving may be anywhere between 50 and 75 per cent, dependent upon the degree to which sand, flasks, etc., are moved off the foundry floor, giving additional room for the molder to work and enabling molders' floors to be spaced closer together, thus relieving the molder from having to shovel sand and carry mold to pouring line. The increased production in snap flask and light work may be increased 50 to 400 per cent. For heavier work, where large piles of sand are, under the old method, piled on the floor, its removal to suitable hoppers performs wonders in making the foundry a better place to work in and a more economical manufacturing unit.

In continuous sand handling, mold conveying and pouring systems, less flask equipment is needed. This means a decided saving in equipment cost of flasks, also the elimination of night work in cleaning up, etc.

Preparing Sand

In the older type of foundry, sand can be cut over with a portable sand cutter or by a grab bucket. The saving through the use of a portable sand cutter, made under our supervision, was as follows:

Sand cutting machine—portable—electric.

Cutting sand by hand—19 piles each evening to be prepared for next day's work.

By hand, this cost \$16.03 per day or 85 cents per pile and required the service of ten laborers for four hours, including 15 per cent supervision and overhead—total of 98 cents $\times$ 19 or \$18.62. When an electric operated sand cutter was purchased, this cost was reduced to 32 cents per pile $\times$ 19 or \$6.08 per day, a reduction of 62 per cent in labor cost. The cost of repairs, current, maintenance and depreciation on the sand cutting equipment

amounted to \$660.00 per year—\$2.20 per day maintenance and fixed charges in addition of 12 cents per pile to the labor cost, a total of 44 cents per pile against total cost by hand cutting of 98 cents, a total reduction of 55 per cent or of \$10.34 per day. This for a foundry operated full time would represent a saving of $\$10.34 \times 300$ or \$3,102.00 per year, sufficient to pay for such a machine the first eighteen months it was in operation.

Another important handling factor is in renewing and rebonding of sand for molding floor use. This can be effectively done by properly designed and installed sand preparing and bonding units. Sand costs are reduced 20 to 50 per cent. Much has been written on this sand renewing proposition, but it is no longer an experiment. Its adoption by any fair sized foundry is a decided economy and within the next few years this method will be so standardized, both for grain size and percentage of bonding material and other factors, that natural molding sands will tend to become obsolete and too costly to find a market.

We mention this, because it behooves the progressive foundryman to look into the future and nothing is so positive as the tendency in this direction. One of the largest molding sand producers in the eastern states possessing this vision is well on the way in developing a method of bonding silica sand for molding purposes and in a manner that will meet specifications consistently on all shipments from his shipping point.

The large foundry operator will, however, in many cases, undertake the working out of this sand proposition himself through the installation of sand handling and renewing equipment, and the smaller foundry will be able to purchase his sand requirements to standard specifications with the assurance that he will continuously get the exact grade and conditions that he requires.

A few pertinent figures may be quoted here from a recent letter covering the experience of a foundry in Northern New York State, with sand reconditioning machinery and conveyors installed to enable them to maintain high quality of production for compressor cylinders and other high grade work. "The time

has been long enough to prove that the machinery merely from a labor saving viewpoint is profitable. The annual charges with amortization at ten years, interest, estimated upkeep and power costs, total \$7,135.00 per year. The labor saving actually accomplished is, for re-milling, two men all night, one man all day, and on the shake-out crew two men all night, which for 300 days per year is an annual saving of \$7,695.00, more than enough to offset the annual charges. In addition, there is the increased production made possible by the additional molding floor space secured by the elimination of sand piles; 5,000 pounds additional production a day is certainly conservative. How much of this increased capacity will be required will vary. If we assume one-half of the time, we would have an increased production of 750,000 pounds per year and this increase in production would not increase certain items of operating expense. The total of such items averaged 1.4 cent per pound for last year, so this saving on the above basis will be \$10,500.00. This can be presented,

Annual charges	\$7,135.00
Saving labor, per year.....	\$ 7,695.00
Saving on increased production.....	10,500.00
	\$18,195.00
Less annual charges.....	7,135.00
Profit	\$11,060.00

which is a very satisfactory profit on the investment, and in addition there is the very great value of a uniform sand mixture."

Dust Collection and Handling

With the increased attention which is today given to healthful working conditions and maintenance of equipment, by no means the least important of foundry handling problems is the elimination of dust from tumbling barrels, grinders, sand blast apparatus and the atmosphere of the foundry in general.

There are two types of dust collectors which are commonly used for the separation of dust from air, namely, the centrifugal or cyclone type and the cloth screen type.

On smaller installations where total dust elimination is unnecessary or in temporary installations where first cost is the governing factor, the cyclone type of collector is frequently used. This collector effects its separation by a combination of centrifugal force and sudden reduction in velocity of the incoming dust laden air. The disadvantages of this type of collector are two fold.

First:—Its efficiency seldom exceeds from 75 to 85 per cent, thus releasing to the atmosphere from 15 to 25 per cent of the incoming dust. It must be remembered that this dust which is released to the atmosphere is the portion which from the standpoint of healthful working conditions is the most harmful, it being finely divided particles minute in size.

This fine dust is released because the natural action of the cyclone is that of centrifugal force and reduction in velocities, the heavier particles, therefore, settling or being thrown out of the air stream but the lighter and smaller particles being carried with the air discharging from the outlet of the collector.

Second:—Due to the centrifugal action of the cyclone type collector there is produced a scouring or blasting action which makes for short life and frequent patching or renewal. In one case we had to entirely cover a cyclone collector body and base with cement coating on this account.

In contemplation of the use of this type of collector precautions should be taken that it be of ample size, for which certain limits, the larger the collector the more efficient will be the separation and the less will be the back pressure on the exhauster.

The cloth screen dust collector is a more modern development in the field of dust elimination and is of a more efficient type. With this type of collector a complete separation is possible. The collector generally consists of a steel case subdivided into a dust side, where the dust laden air enters a series of cloth covered screens, and a clean air side to which, in most installations, the exhauster is connected. In operation the dust laden air is drawn into the dust side of the collector and is deflected by means of heavy baffle plates to prevent direct blasting action on

the screens. The dust impinges on the outer surfaces of the series of cloth covered screens, with the cleaned air being drawn through the cloth and out of the clean air side of the collector to the exhauster. Although it is possible to install the exhauster ahead of the collector blowing the dust laden air into the collector and putting it under pressure, it will readily be seen that where abrasive dust is being collected the wear on the exhauster will be excessive. For this reason the collector is usually installed under suction whereby the exhauster handles only clean air from which the dust has been separated.

The dust which is shaken from the screens of the collector into the dust tight hoppers below can be removed by several methods. The simplest and perhaps most commonly used is by placing bags or other receptacles below the discharge gates on the hoppers and emptying the hoppers manually. Then again, where height permits, the dust may be discharged manually direct to wagons, cars or trucks. Where the collector is installed at a considerable height, the dust from the hoppers may be spouted to a central unloading point. However, when the collector is large and equipped with a number of hoppers, the dust is most efficiently removed mechanically. This is accomplished by fitting mechanically driven rotary discharge valves to the bottoms of the hoppers. These valves in turn discharge to any desired container or truck or to a dust tight conveyor of the spiral, belt or drag type. By this latter method the dust may be conveyed entirely mechanically to a central unloading point with a considerable saving in labor. The valves and unloading conveyor may be operated continuously or periodically, dependent upon the quantity of dust accumulated during a given period of operation. Regardless of the unloading system used, the hoppers should be emptied frequently and thoroughly, and the discharge gates kept tightly closed with the system in operation.

The Exhauster.—The exhauster to be used in conjunction with any given piping system and collector must be carefully selected as there are a number of variables which enter into the consideration. Ordinarily there are two or three different ex-

hausters which might be used with any system but usually only one which will fulfill all of the necessary requirements. With the piping system completely designed and the collector selected, careful calculations should be made of air volumes and velocities together with pipe friction and losses to determine the conditions under which the exhauster is to operate. When this result is known an exhauster should be selected which is equipped with the most satisfactory design of wheel for the conditions to be encountered. The exhauster selected should operate at the highest efficiency which it is possible to obtain, resulting in the minimum of power consumption. It should be well balanced, substantially constructed and preferably of a standard type. The bearings should be large and well lubricated and preferably of the anti-friction type, which cost very little additional. Care should be taken in mounting the exhauster and where possible it should be installed on a concrete foundation and solidly bolted down. It is usually advisable to install a slide gate at the inlet of the exhauster to provide for air adjustments.

The dust which is shaken from the screens of the collector is commonly collected in suitable hoppers, installed high enough so that a truck can be backed under same, and the hopper load dumped by a release valve.

A good type of exhauster is also required with due consideration given to conditions that have to be met.

Such a dust collecting outfit is a very necessary investment in a foundry, both from health and the proper maintenance of machinery and equipment, that would otherwise suffer seriously from dust troubles, as well as improving the appearance of castings as they come from tumbling barrels and sand blast equipment.

In closing we feel that we have only glossed over in a very general way the more common handling equipment of a modern foundry. If it induces any of you to improve your handling facilities we will be more than gratified.

High Test Cast Iron*

By R. P. LEMOINE,† PARIS

Introduction

The present paper deals with the actual state of the production of high test cast iron in Europe and chiefly in France.

So much has been published on this subject during the last few years in papers of a purely scientific spirit that one may wonder if all the newly-proposed processes are really applied on a commercial scale and, among them, which are the most practical and liable of an important industrial development.

It is intended here to examine the subject from this last point of view and then to study the uniformity of results obtained from day to day in routine work rather than the relative value of figures published about tests concerning one process or the other.

The paper is divided into two main parts: the first reviews the various scientific results which are at the basis of the modern tendency in high test cast iron production; the second treats of the evolution of the practical side of the question during the last ten years.

REVIEW OF SCIENTIFIC RESULTS

The expression "High Test Cast Iron" will be understood here as meaning cast iron of high mechanical properties: tensile, bending, shearing and impact strengths. Such properties are known to depend directly in gray cast iron upon constitution and structure.

*Annual Exchange Paper of the Association Technique de Fonderie, France.

†Consulting Engineer and member of the French Foundry Technical Association. Discussion of this paper begins on page 729.

Constitution means the chemical nature and relative proportions of the different elements and compounds (also called constituents) to be seen under a microscope. These constituents are chiefly in the present case:

Graphite—No resistance at all. Breaks the uniformity of the metallic (matrix) part of the cast iron.

Ferrite—Soft and malleable.

Pearlite—The most resistant of all.

Cementite—Hard and brittle.

Structure is the size and arrangement of the different constituents; for instance, graphite can be fine and uniformly distributed or appear in large and segregated flakes; pearlite can be coarse or, on the contrary, "emulsified."

Whatever its total carbon, a gray iron-carbon alloy can have, in first approximation, three typical constitutions according to its combined carbon.

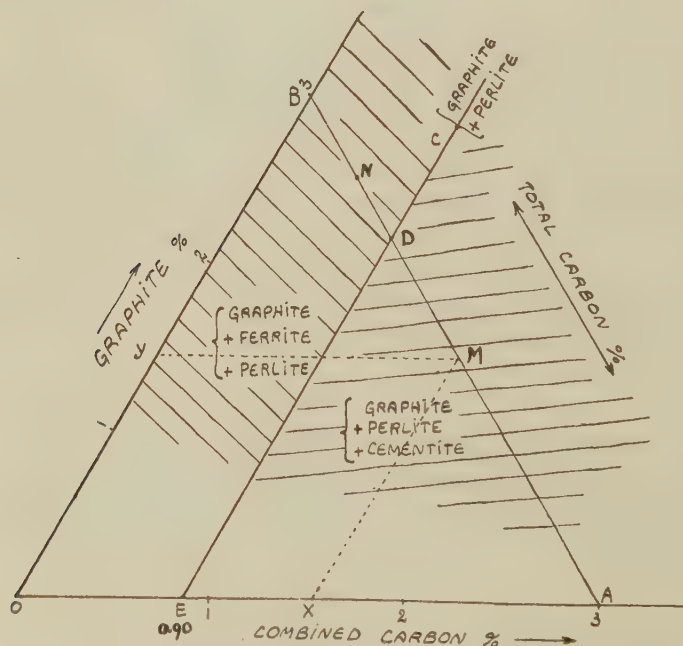


FIG. 1.—DIAGRAM OF CONSTITUTION (A. PORTEVIN)

1. If combined carbon is about 0.90 per cent, all the metallic part of the alloy is constituted of pearlite and the total constitution is: graphite-pearlite.

2. If combined carbon is lower than 0.90 per cent, the metallic part is constituted, like an hypo-eutectoid steel, by ferrite and pearlite, and the total constitution is: graphite-ferrite-pearlite.

3. If combined carbon is higher than 0.90 per cent, the metallic part is constituted, like an hyper-eutectoid steel, by pearlite and cementite, and the total constitution is: graphite-pearlite-cementite.

It is very convenient to visualize these indications on a diagram invented by A. Portevin, and use it to study or explain the relations between constitution and mechanical properties.

This diagram (Fig 1) is simply built up in an angle of 60 degrees. Combined carbon per cent is reported along O A and graphite per cent is reported along O B. Point M, for instance, is representative of an iron-carbon alloy with O X or Y M combined carbon per cent and O Y or X M graphite per cent, and as we have:

$$X M + Y M = A M + M B = A B$$

the length of A B or O A or O B represents the total carbon.

On this diagram, all the alloys whose constitution is graphite-pearlite have their representative point on line E D (0.90 per cent combined carbon). All the alloys whose constitutions are graphite-ferrite-pearlite have their representative point in the area at the left of line E D (less than 0.90 per cent combined carbon), and all the alloys whose constitutions are graphite-pearlite-cementite have their representative point in the area at the right of line E D (more than 0.90 per cent combined carbon).

As for the relations between constitution, structure and mechanical properties:

(a) It has been recognized since 1917 by A. Portevin¹ that among all the gray cast irons with the same total carbon, the best mechanical properties correspond always to the one whose con-

¹A. Portevin—*Microstructure des Fontes Aciérées*. *Revue de Métallurgie*, vol XIX, p. 227, 1922.

stitution is graphite-pearlite; for instance, among all the cast irons represented by line A B (same total carbon), the best one is D.

(b) Experience has shown that if, in practice, it is difficult to surely obtain the desired combined carbon, it is better to have some free cementite (representative point between D and A) than some free ferrite (representative point between D and B): the first one is less detrimental than the second.

(c) Experience also shows that among all gray cast irons with the same combined carbon, 0.90 per cent, for instance, the best one corresponds always to the lowest total carbon. This is due to an intervention of structure: when the total carbon diminishes from 4.30 down to 2.00 per cent, for instance, the graphite gets finer and finer, thence leading to better mechanical properties, because the uniformity of the pearlite is less badly broken.

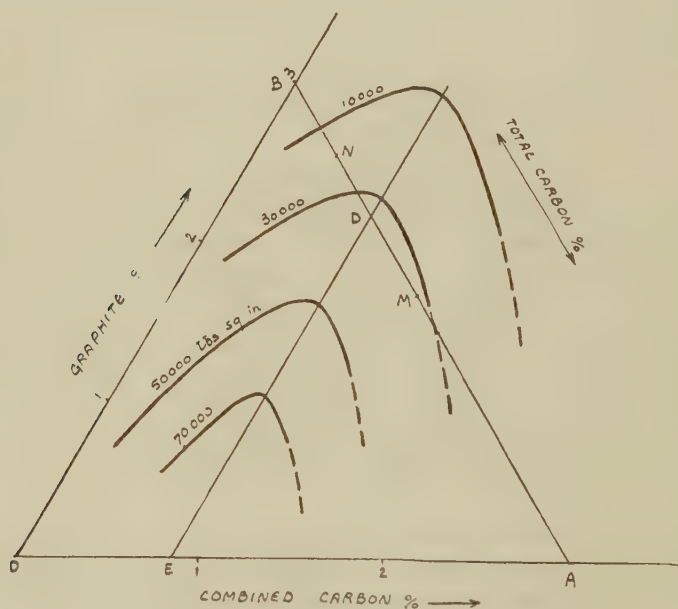


FIG. 2—INFLUENCE OF CONSTITUTION AND SIZE OF GRAPHITE ON TENSILE STRENGTH

The combination of the three considerations (a), (b) and (c) permits us to draw qualitatively on the diagram Fig. 2 curves of equal strength (tensile, for instance). Due to (b) they are more flat at the right of line E D than at the left.

Figures are, of course, only indicative, as they do not correspond yet to a definite process of fabrication and can still vary with further interventions of structure.

Influence of Cooling Speed

For a cast iron of given total carbon, cooling speed determines the contents in graphite and combined carbon, thence the position of the representative point of the final constitution, and, all other things remaining constant, it has a direct influence on mechanical properties, as can be seen on the diagram.

When a certain cooling speed leads, for instance, to representative point M, for a cast iron with AB per cent total carbon, if this speed is diminished, the point moves toward D and B, properties improve until D and decrease afterwards; if the cooling speed is increased, the point moves toward A, and properties always deteriorate. The contrary can be said when the original cooling speed leads to a point like N placed between D and B.

In a section of a casting, cooling speed varies from one point to the other, and it may occur that when surfaces are represented by M, the central part has a constitution corresponding to N and the highest properties can be found only at a certain depth. The same applies to two different sections of the same casting and also to a casting and its so-called "representative test bar."

In this last case, in spite of having been cast with the same liquid iron, the two pieces may have widely different mechanical properties, and hence different average or aggregate strengths.

It is quite clear from this that the problem of improvement of cast iron must be studied on definite principles: try first to diminish or even suppress the heterogeneity due to variations of cooling speed before trying to get very high figures out of test bars of given dimensions. This point has been neglected by many investigators, and one object of this paper is to put the question in its right place.

Influence of Silicon

Silicon has, at first sight, an influence similar to that of cooling speed. It can be described in about the same manner as on the diagram Fig. 2.

When a definite part of a casting is represented by a point like M, if silicon is increased, all other conditions being unchanged, the representative point moves toward D and properties improve; after D they decrease. They also decrease when silicon is diminished and point M moves toward A.

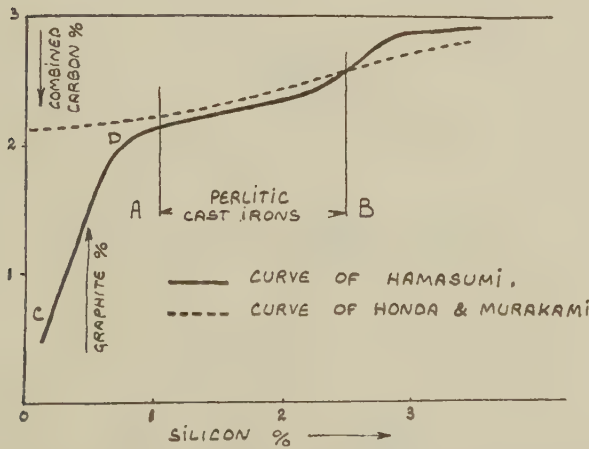
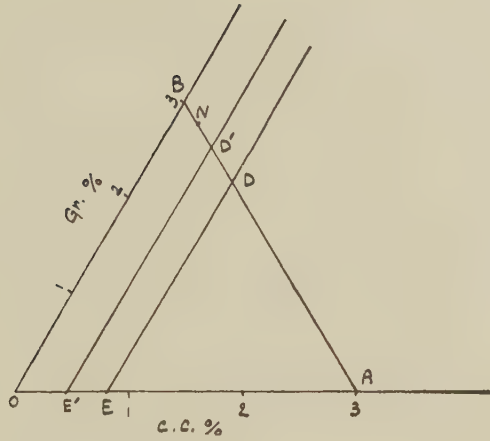
In fact, the consequence of these evolutions is really more intricate than just said on account of the following considerations:

1. When silicon increases in cast iron, the carbon content of the pearlite diminishes. If we refer to the diagram, this means that: when there is no silicon at all (pure iron carbon alloys) the carbon content of the pearlite is about 0.90 per cent; when some silicon is added, line E D moves leftward and with it move the curves of equal strength.

It may then arrive that (Fig. 3) when for a certain silicon content the maximum strength corresponds to D (graphite-pearlite constitution) and the representative point of a cast iron is N, if the silicon is diminished to move N toward D', D' moves also toward D and no improvement can be reached.

On the other hand, it may also happen that, when in the previous conditions the representative point of a cast iron is D itself, variations of silicon within certain limits are followed by such correlative motions of the representative point and D that the two remain superposed and the cast iron does not lose its high strength in spite of its changing silicon.

This last case does exist in practice and appears clearly when drawing on the same diagram (Fig. 4) the results published by Hamasumi (*Influence of Silicon on the Graphite Content of a Cast Iron of Invariable Total Carbon*) and Honda and Murakami (*Influence of Silicon on Carbon Content of Pearlite*). The comparison of the two curves shows that within the range A B of silicon contents, any increase of this element is followed by a slight increase of graphite and such a diminution of carbon in the



pearlite that the constitution remains always approximately graphite-pearlite.

2. The length of the interval A B is not the same for any total carbon and for any cooling speed.

It has been recognized that the lower the total carbon, the longer the interval A B. As for the influence of cooling speed, no valuable data have as yet been published, but practical experience shows that when a low total carbon is adopted (2.40 per cent, for instance), the interval A B spreads toward high silicon contents, and if a high figure is chosen for this element, any cooling speed within reasonable limits leads to the graphite-pearlite constitution, because the influence of this factor is no longer effective in presence of much silicon to rule over graphitization.

An interval does exist inside A B and near B in which low carbon cast irons show no reaction to cooling speed; in large sections that have throughout the same constitution and structure, the mechanical properties are the same whatever the wall thickness.

The practical importance of this fact cannot be over-estimated, because it meets the main condition of improvement of high test cast iron.

To summarize, we can realize all the technical value of a low total carbon coupled with a high silicon. This solution gives:

(a)—Homogeneity of constitution, structure, and hence of strength.

(b)—Fine graphite leading to high strength.

We shall see later that the best practice is inspired by this outstanding principle.

Influence of Phosphorus

This element has always been feared in high test cast iron, but it does not seem that its content must be very low. Wüst and Stotz have found that bending strength increases with the phosphorus up to 0.30 per cent and diminishes afterwards. In practice, this element can be kept without inconvenience around 0.15 per cent.

Influence of Manganese

Manganese, like silicon, diminishes the carbon content of pearlite and, up to a point variable with the total carbon of the iron, it increases slightly the bending strength. In presence of a moderate amount of sulphur there is no reason to raise the manganese up to more than 0.80 per cent.

Influence of Sulphur

The same as in any cast iron, the content must be as low as possible.

These last three elements, when used as stated, have only a very small influence on the mechanical properties of high test cast iron.

REVIEW OF PRACTICAL RESULTS

After having studied in the preceding chapter the various scientific results concerning high test cast iron, we will now examine the evolution of the processes of production in the past ten years. For this purpose we will take as a basis of comparison the cast iron from partial steel charges used for making shells.

Use of Steel in Producing Cast Iron

Many foundries became quite expert during the war in the manufacture of cast iron shells, using some steel in the mixtures. The thorough study of mass production of well-known castings of this kind has resulted in the establishment of definite rules as far as chemical composition and operation of the cupola are concerned.

The final carbon content aimed at was around 3 per cent. This figure was recognized at that time as the lowest a cupola could give with a good uniformity; it also can be said that the advisability of lower figures was not then ascertained. The obtaining of this carbon content involved the use of steel scrap in the charge.

To contend with a fairly severe impact test, it was thought indispensable to keep the phosphorus low (about 0.10 per cent).

In such conditions the silicon was adjusted to the carbon so as to have:

Total carbon + silicon < (less than) 4.4 %

Under this maximum limit, the silicon content was itself governed by the thickness of walls and by the fact that shells were cast either in green or in dry sand molds; for instance, a silicon of 1.20 per cent for a given shell in dry sand was increased to 1.35 per cent to give the same results in green sand.

The remainder of the chemical composition was more or less invariable for any shape of shells; for instance, the optimum analysis for a wall thickness between 30 and 45 millimeters was:

C: 3.10%—Si: 1.25%—Mn: 0.80%—P: 0.10%—S: 0.10%
and manganese, phosphorus and sulphur were about the same as for any other combinations of carbon and silicon.

Cupola charges able to give such final results were chiefly composed of low phosphorus pig iron and steel scrap. The object of this last material was, of course, to diminish the carbon and silicon of the pig iron.

At the same time, the best grade of scrap for the purpose was found to be mild or hard carbon steel (rails) in fairly heavy pieces. The percentage added varied widely from one foundry to the other, not only on account of variations in the analysis of the available pig iron, but also because the recarburization of the steel was not the same in every cupola. In some cases the reduction of the carbon content of the final iron with a given addition of steel scrap was more efficient than in others, and the figures had to be established for each cupola. This was, of course, quite a simple thing, done during the first days of manufacture.

The composition of the charges included also scrap of iron from the partial steel mixtures scrap (heads, gates, rejected castings).

The description of the molding, coring and casting of shells is outside the scope of this paper; let us only note that in some instances, when shells of widely different size had to be cast the same day, it was found convenient in several foundries to use for them all the mixture suitable for the largest, and merely heat up the molds of the smallest to a given temperature, so as to obtain for those castings the same rate of cooling which gave the desired results in the largest ones.

All the shells had, of course, to satisfy a set of definite tests

(porosity under water and gas pressure). The iron itself was controlled by tensile, impact and bending tests. The specifications for tensile test were those given in Table 1.

Table 1

Test bars cast at:	
Length	200 mm.
Diameter	18 mm.
Machined to:	
Length	100 mm.
Diameter	16 mm.
Tensile strength: more than 25 kg. per square mm. (more than 35,575 lbs. per sq. in.)	

When the specifications of Table 1 were strictly followed, the usual strength was around 28 kilograms per square millimeter (39,840 lbs. per sq. in.).

As already said, A. Portevin made an extensive study of such shells and found out that the correct figure of mechanical properties always corresponded to a pearlitic structure; the iron was composed only of pearlite and graphite.

Just after the war, the process used with great success for shells was extended to several kinds of castings like cylinders and heads for Diesel engines. It is always followed even now by some leading firms and a national naval yard in France.

In some instances it was found that more phosphorus than was originally used would help much for castings of intricate shape and presenting thin sections. However, practice indicated that the maximum value of the sum: Total carbon + silicon had to be increased with the phosphorus.

A. Levi worked out a new rule: "When phosphorus increases from 0.30 to 0.80 per cent, the expression:

$$4.6\% < \text{total carbon} + \text{silicon} < 5.20\%$$

must be satisfied in order to obtain satisfactory mechanical properties." (Tensile strength always higher than 20 Kg. sq. mm. or 28,450 lbs. sq. inch).

From a strictly technical point of view, iron made from a partial steel mix with low or mild phosphorus would have been satisfactory for many applications if it were possible to get a reasonable uniformity of strength throughout a given casting of variable thickness. In fact, it was not the case, and this is illus-

trated by the figures collected by A. Le Thomas;² some of these figures are reproduced in Fig. 5.

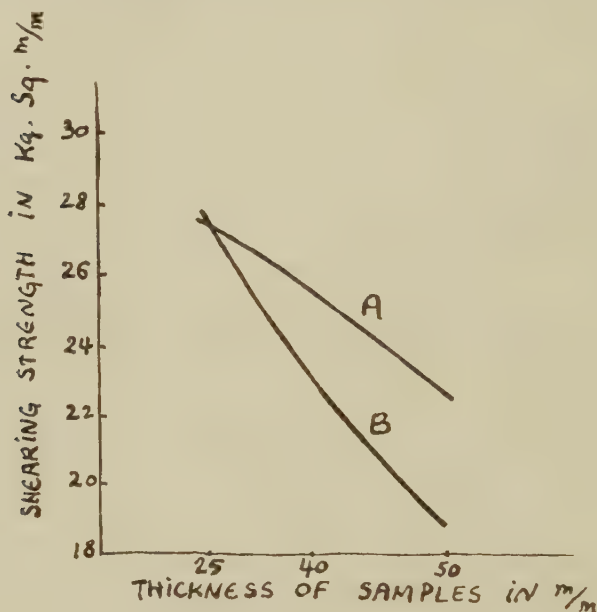


FIG. 5

CURVE COMPOSITION:		A			B		
G—V	C.	= 3.07			= 2.92		
	Si.	= 1.02			= 1.45		
	Mn.	= 0.54			= 0.77		
	P.	= 0.25			= 0.20		
	S.	= 0.06			= 0.05		
THICKNESS OF SAMPLES:		25 mm.	40 mm.	50 mm.	25 mm.	40 mm.	60 mm.
BRINELL HARDNESS		228	205	190	229	208	190
SHEARING STRENGTH		27.4	25.8	22.6	28	22.9	18.4

Patented Cast Irons

Some years ago there appeared on the European market several patented processes claiming to be able to produce high test cast iron with properties never reached before. The most well known are the Lanz and the Thyssen-Emmel processes.

The feature of the first one is to produce a so-called "Perlit Iron" by casting a cupola melted iron in molds heated up to a definite temperature so as to get a definite rate of cooling. This

²A. Le Thomas—*Testing Cast Iron*, Transactions American Foundrymen's Association, vol. XXXIV, pp. 690-745, 1926.

temperature is adjusted to the thickness of the castings and two or three different mixtures in the cupola are sufficient to cover the range of common thicknesses.

The chemical compositions look much like those of irons from partial steel mixtures with a little less silicon.

The claims of the patent are well known: uniformity of a "Perlit" structure, graphite in small particles, etc.

The originality of such a process does not need even to be discussed, because it does not exist. Casting in hot molds has been practiced by various foundries during the war and also many years before, as Prof. Osann himself recalled.³ The rate of cooling is one of the many factors of graphitization and it might as well be governed, if wanted, by the casting temperature, and no reasonable foundryman would have the idea to apply for a patent on this last feature.

As for the technical value of the process, two or three points can be raised:

1. The pearlite structure is not a specialty of the patentees; it has always existed, and its importance in high test cast iron had been recognized long before their patent appeared.

2. It is possible that more uniformity is obtained in a given section of a casting, and differences of structure can be smaller than usual between the central part and the outside, but what about two different sections of the same casting? Variations of one to three in thickness of walls are not rare, and it is impossible to have in a mold the necessary range of temperature to give to each one the desired cooling speed.

3. From the figures published by the patentees it can be seen that, for a given composition of iron, when the mold for a casting one inch thick has to be heated up to 200 degrees Cent., the mold for a casting two inches thick has to be heated up to 450 degrees Cent. Which type of furnace has to be used to have the two molds ready for casting at the same time? What will be the organization of a foundry making by this process castings of very different sizes and thicknesses?

³Osann—*The Manufacture of High Quality Cast Iron*. Foundry Trade Journal, vol. 39, No. 644—pp. 448-449. Translated from "Die Giesserei."

It appears, after careful examination, that in very few instances only the process has a chance to be interesting. As a matter of fact, its success is very small, at least in France.

The Thyssen-Emmel process has for itself the value of a good metallurgical basis. As far as can be ascertained, it allows the direct production, with a cupola, of a cast iron low in carbon and high in silicon.

The question as to whether such a performance is worth being patented will not be discussed here, because the author of this paper obtained, some six years ago, many tons of cast iron with 2.30 per cent carbon out of a cupola without thinking he had done something new.

It can be said that the production of low carbon cast iron in a cupola is a rather intricate operation if considered (as must be done) from the point of view of regularity and uniformity. It depends not only on the cupola itself but also on the raw materials, and this cannot be dealt with by a patent because conditions always vary from one country to another.

This question will be developed in a special chapter.

Alloyed Cast Irons

There appear from time to time in the technical press papers dealing with the influence of some special element on the properties of cast iron.

The author's opinion on this subject is the following:

Special elements are, as a rule, expensive and are to be considered only when it is necessary to further improve a given property, the full possible development of which has been reached when using only the influence of common elements and the best process of fabrication.

The same policy has constantly been applied to alloyed steels. An alloyed steel is always a quality carbon steel, a certain property of which is improved by the addition of a special element up to a degree that warrants the extra cost of the operation.

Alloyed cast irons seem to be worth consideration for different corrosion problems and some applications in the electrical field; they perhaps will be developed in the near future for resist-

ance to wear when their superiority from this point of view is amply proved. But, when high mechanical strengths only are wanted (tensile, shearing and bending), they do not seem to be of much interest up to now, because the full development of such properties as obtainable without these special elements has not yet commonly been reached. As far as mechanical strengths are concerned, alloyed cast iron can be considered as a reserve force to be used for further improvements at the time when the new processes to make high test cast irons are extensively adopted.

Electric Cast Iron

The use of the electric furnace to produce cast iron dates back in France to several years before the war. In some electric steel plants they used to prepare their iron for additions (recarburization of a too soft steel bath) by merely melting steel turnings and scrap and carburize them with coke or anthracite in special heats of an electric furnace. This simple process was extensively used during the war when there was a shortage of pig iron due to many blast furnaces being destroyed. It produced only pig iron and it was not intended at that time to get direct from the electric furnace an iron suitable to be cast into molds.

The question has since been much studied, and the ability of the electric furnace to give cast iron of very good mechanical properties is now well proved. Its two principal advantages are:

1. If a basic bottom is used, there is a possibility of getting any final analysis out of practically any kind of raw material.
2. Refining of the graphite.

The first point is self-explanatory for every one who knows but little about the electric furnace.

The second point is much more intricate and difficult to explain. Refining of the graphite has been attributed to superheating, and at least three theories have been put forward,⁴ but the fact remains positive that superheating sometimes fails to refine the graphite. Prof. Osann⁵ seems rather inclined to think that refining is chiefly due to the following mechanism: As the iron

⁴ Piwowarski—*Progress in the Production of High Test Cast Iron*. Transactions American Foundrymen's Association. vol. XXXIV, pp. 914-985, 1926.

⁵ Loc. cit.

remains a long time liquid in the electric furnace, "kish" or "hyper-eutectic" graphite has the opportunity to get out of the alloy; then graphitization takes place only at the true stable eutectic temperature when the iron cools down in the molds, and, in consequence, the graphite formed is fine.

It is quite possible that the truth lies in the association of all the theories already mentioned, and perhaps also some other one dealing with dissolved gases and their influence on the time and shape of graphitization. An academic discussion along this line would be out of place in this paper, and we will remember only one thing: that under definite conditions of manufacture, a very high test cast iron can be produced with a good degree of safety in an electric furnace. Three particulars will be of interest.

1. As far as the chemical composition is concerned, it is easy in this case and it is advisable to follow the modern tendency to have a low total carbon coupled with a high silicon; for instance, 2.40 to 2.60 per cent carbon with 2.80 to 3.00 per cent silicon. The advantages of this have been exposed in the first chapter of this paper, and there is no need to repeat them.

2. Manganese has to be kept rather low on account of low carbon and sulphur; if possible, it is fixed at 0.40 per cent. For the phosphorus 0.15 per cent seems to be a reasonable figure.

3. Sulphur is cared for by the furnace itself if a basic bottom is used, which is a good proposition in the present case.

It can be seen that the contents of the three last elements agree with the scientific results cited in the first chapter.

As for the process itself, it is much better to start chiefly with steel scrap as raw material and carburize it, than to start with a charge having approximately the final composition wanted. It is perhaps a little more difficult to run the heat, but the possibility of obtaining a very fine graphite is much larger. This solution is also interesting from the point of view of cost, as a bad steel scrap can be used without inconvenience and such material is generally two or three times cheaper than pig iron.

Powdered coke, graphite or anthracite is mixed in liberal quantities with the cold scrap and no special difficulty is found in

getting 2 to 2.40 per cent carbon in the bath just after melting down. The desired point is reached by the subsequent action of a carburizing slag during a quarter to half an hour, and the operation is controlled by a quick chemical analysis or by examination of a broken chilled sample; the latter method is not very accurate, because the iron is all white at this time, but the coarseness of crystallization is often a sufficient feature of appreciation.

When only steel scrap is used, silicon has, of course, to be added, and the question arises, is it better to add it with the cold scrap or afterwards when the bath is liquid? The writer prefers to add silicon in small quantities at a time when the carbonizing operation is finished and the temperature rises; the effect of each addition is controlled by recording the depth of chill and size of grain of small pointed samples cast in green sand.

This practice is the best one to be sure that in spite of eventual erratic losses of silicon, the remainder of this element is well adapted to the actual carbon content of the iron.

When the heat is well managed, the resulting cast iron gives with the test bars used for (a partial steel mixture) more than 40 Kg. per sq. mm. tensile strength (56,920 lbs. per sq. in.). It has very fine graphite, appearing chiefly in dots under the microscope and uniform pearlite. The homogeneity of such cast iron is very good and no appreciable difference can be noticed in constitution and structure between the central parts and the outside of a casting two inches thick.

Duplex Process

The main objection against the use of an electric furnace to melt cast iron is the cost (current, electrodes, amortization, etc.). The power consumption in the method just described varies around 600 K. W. H. per ton of liquid iron, and it is clear that its interest is limited to countries or districts where electric current is very cheap. Moreover, it can be said that if the electric furnace is perfect for refining, it is expensive for melting and not very convenient to carburize steel beyond a certain point. For those purposes, a foundry cupola is much more efficient. This consideration is at the basis of the duplex process, which

consists in melting the steel scrap and carburizing it in a cupola and transferring the liquid iron in an electric furnace, where it is refined after its composition has been corrected, if necessary.

A short description of the operations is in order. The chemical composition aimed at is the same as previously indicated. The steel scrap is charged in the cupola and everything is done in order to get an iron running at the tap hole with about the final carbon content wanted (see details in the next section on cupola low carbon cast iron). The liquid iron is transported in ladles to the electric furnace and, at the same moment, the carbon is tested. When the result is known, corrections are performed, if necessary, by:

1. Adding soft steel scrap in the furnace if the carbon is too high.

2. Building up a carburizing slag if the carbon is too low.

The first correction is more easy and accurate than the second, but, anyway, the two mean a loss of time and consumption of current, and their necessity must be avoided as far as possible.

When the carbon is right, a small deoxidizing slag is made up, if not already done for recarburization purposes, and as soon as the temperature rises, additions of silicon are made. The results are controlled as in the preceding process on small test samples.

The quality of the final product is the same as if it were completely prepared in the electric furnace, and its price is much lower in normal conditions.

The power consumption depends largely upon the organization of the shop. A duplex operation needs from 35 to 50 minutes of work at the electric furnace (charging and tapping included) when the furnace has not had time to cool down much between two operations, and the power consumption is about 125 to 175 K.W.H. per ton. If the melting capacity of the cupola is not well adapted, if there is a delay between two operations, or if much work is needed to correct the carbon content, the power consumption increases. In any case, however, there is a substantial difference with the single process from this point of view.

When trying to make a fair comparison of cost between the

semi-steel, for instance, and the duplex processes, two important features are to be considered:

1. Cost of raw materials.
2. Cost of electric furnace operation.

In many parts of Europe, steel scrap suitable for the duplex process is so much cheaper than the low phosphorus pig iron necessary for semi-steel that there is a substantial interval in which the cost of electric furnace operation can vary without losing its economic advantage.

Even if an extra commercial value is not considered for the electric final product, it is often found that its manufacture remains interesting up to the normal price of electric current in several industrial districts. Moreover, a duplex equipment gives a foundry the possibility of producing several kinds of special cast iron and even cast steel, a point worth being considered commercially.

Cupola Low Carbon Cast Iron

It is a fact that long practice with the duplex process has taught much about the production of a low carbon cast iron with a cupola.

The compelling need to cut down current consumption has obliged the practical man always to try and avoid carbon correction in the electric furnace, and, for this, to get the right contents at the tap hole of the cupola. Such a performance has been attained gradually.

Much has been said and published about the carburization of steel scrap in a foundry cupola, but the writer's opinion, based on extensive experiments in five countries of Europe, is that this operation can be divided into two main steps: carburization of solid steel scrap before melting and carburization of liquid iron after melting.

1. When considering a given cupola and a certain kind of soft or mild steel scrap, it is always possible to combine the weight of charges, pressure and volume of air so as to get an iron with not more than 2.00 per cent carbon when it melts down and falls in drops in front of the tuyeres.

The only important point to reach is to have a high melting speed, and we will try to explain this.

It is obvious that the scrap melts down only when its melting temperature gets lower than the temperature of the combustion zone of the cupola. As it goes down from the charging door, it picks up carbon at a rate depending upon its nature, thickness, etc., and it arrives in the combustion zone with a certain carbon content varying with the time of travel. If the temperature of this zone is high enough, the carburized scrap melts down; if not, it remains there and continues to pick up carbon until its melting point is sufficiently lowered.

It appears then to be a relation between the temperature of the combustion zone and the carbon of the scrap when it melts down; the higher the temperature, the lower the carbon. But this is only true providing the high temperature is secured by a quick burning of a moderate percentage of coke and not by large quantities of coke burnt at low speed.

It is a mistake to think that much coke is needed to melt all steel charges in a cupola; 12 to 14 per cent of the charges are sufficient. If, for instance, 20 per cent is used, it becomes difficult to obtain low carbon cast iron, because the time necessary to burn all the coke is long, the melting speed is low, and the scrap has time to pick up too much carbon during its travel from the charging door down to the combustion zone.

A quick burning of 12 to 14 per cent of coke and a quick melting are obtained only by increasing the volume of blown air, and if the tuyeres section remains the same, by increasing the pressure.

As a matter of experience, the writer can state that he has obtained with the same cupola and same charges an iron with 2.00 or 3.00 per cent carbon when it fell liquid in front of the tuyeres when the air pressure was 450 or 160 millimeters of water. In the first case the melting speed was almost twice as high as in the second; that is to say, twice as much iron was melted per hour and, of course, twice as much coke burnt in the cupola. That is the entire secret of the operation.

2. It is common in Europe to use cupolas with bottom re-

ceivers; a certain capacity is provided in the apparatus itself under the tuyeres' level; this capacity is full of coke and the iron is collected and kept hot there before being tapped.

It is obvious that the iron has the opportunity to pick up some more carbon in such bottom receivers, and it actually does so to an extent varying with the time of contact with the coke and with its own chemical analysis.

One may wonder now what is the best way to produce a cast iron with, for instance, 2.5 per cent final carbon. Is it better to use a cupola with very low tuyeres and no bottom receiver at all and run it so as to get 2.5 per cent carbon in the scrap at the moment it melts down; or is it better to use a cupola with a bottom receiver, run it so as to get 1.8 to 2 per cent when the scrap melts down and let the iron pick up 0.70 to 0.50 per cent more carbon in the coke bed of the bottom of the cupola?

When such final carbon is aimed at (as is the case in the described duplex process), the writer prefers the second proposition, because he has discovered that the iron is always more hot and fluid. This is quite understandable, as in the first case the iron has but little extra heat in excess of its melting temperature, whereas in the second case the same extra heat is increased afterwards by at least 50 degrees Cent., when the liquid iron picks up 0.50 to 0.70 per cent carbon and its melting temperature diminishes.

The important question about the use of the second proposition is to know how to regulate the carbon as it is picked up in the bottom receiver. This can be done in at least three ways:

(a) Tapping at definite intervals. This may be interesting in practice if the iron is collected in a specially heated ladle, a barrel ladle with a burner, for instance (a fairly expensive solution); otherwise it is not convenient, because the tapping time is not always at the disposal of the cupola man.

(b) Adjust the capacity of the bottom receiver, which has a lining of definite thickness, to the time wanted for the iron to remain in contact with the coke, and tap when the receiver is full. This solution is about the same as the preceding one and also has its inconveniences.

(c) Up to a definite level, replace pieces of coke with pieces of brick in a hollow bottom receiver. The extra carburization wanted is performed when the liquid iron drops fall from one piece of coke to the other in the top part of the receiver and ceases afterwards. This solution is probably the best one; it unites the advantage of a carburizing receiver of limited capacity to the interest of a naturally hot forehearth or heated ladle. Experience has proved that iron drops can pick up 0.50 to 0.80 per cent carbon in rapid contacts with pieces of coke when these pieces are free of slag, which is the case in the present instance, as slag falls under the coke bed providing it is fluid enough. Of course, each drop does not always pick up the same amount of carbon, but the average appears to be uniform in practice.

In conclusion, it can be said that, as far as the final carbon content only is concerned, very low carbon cast iron can be produced in a cupola out of steel scrap charges only with a good degree of accuracy, and hot enough to withstand fairly long translations to the electric furnace.

Such iron, when it comes from rusty scrap, is wild and seems strongly oxidized. This does not matter at all in the duplex process, because a convenient slag takes care of it easily and quickly in the electric furnace; but, it is important to consider this fact when trying to get from a cupola a low carbon cast iron suitable to be cast directly in molds.

Cupola High Test Cast Iron

At this stage of our knowledge, it is natural to wonder if it is not possible to improve substantially the semi-steel process and get, direct from a cupola, cast iron of high and uniform mechanical properties coupled with good molding qualities. The right technical procedure is well known: reduce the carbon and increase the silicon of semi-steel to get a fine graphite and always the graphite-pearlite constitution throughout widely different thicknesses.

The beginning of a practical solution along this line may appear from what has been said about running the cupola for the

duplex process, but the two things are really very different. When working at the cupola for the duplex process, all the efforts are spent to get the uniformity of carbon content of the iron with the safe impression that, in case of failure, the electric furnace is always there to make any necessary correction and only the cost would be affected. There is no preoccupation at all about silicon, wildness and molding ability.

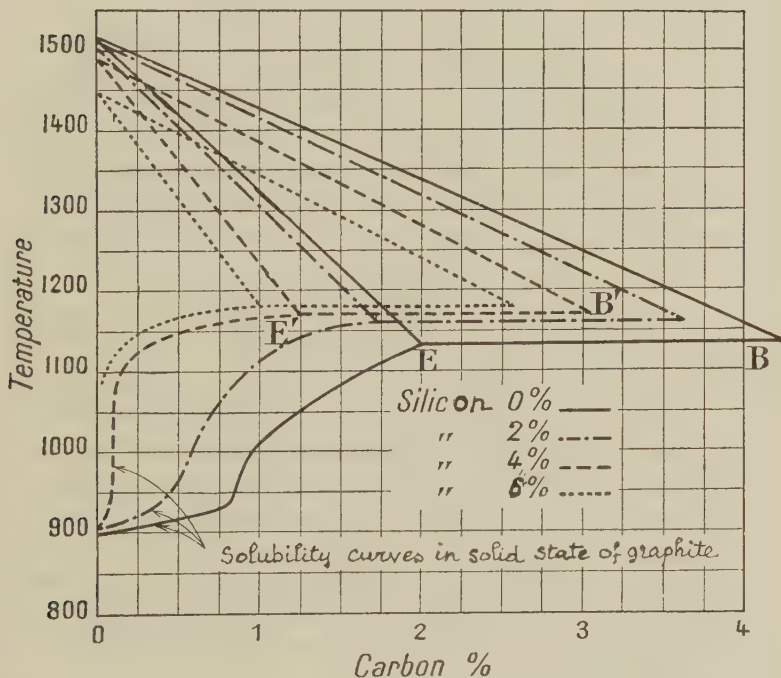


FIG. 6

Conditions are not the same in the case we are now considering. The iron must be directly hot and fluid enough, not over-oxidized, and must have a fairly uniform silicon content. Extensive experience has shown that a good and practical solution can be reached by studying more efficiently the behavior of the cupola

and using selected raw materials. We are going to give some particulars about this and consider things from three most important points of view: fluidity of the iron, oxidation and uniformity of chemical composition, and quality and cost.

1. *Fluidity.* It can be seen from the influence of silicon on the iron-carbon equilibrium diagram that this element lowers the temperature of the beginning of solidification. The curves (Fig. 6) show that the "liquidus" temperature is about the same for the two following compositions:

Carbon 3%	—silicon 0.50%	(1)
Carbon 2.60%	—silicon 3%	(2)

The first one corresponds to a white heart malleable (cupola product), which is used to cast very thin pieces like small fittings, and there is no reason for the second (not very far from a high test cast iron) not to be fluid enough for common foundry work when it is produced only in a cupola. As a matter of fact, no real difficulty is met along this line.

2. *Oxidation and uniformity of chemical composition.* These two correlative points are the most difficult to handle.

It has been said that making low carbon cast iron with a cupola involves in general a fairly strong blast, and this fact increases the importance of the following reactions: When the liquid drops fall in front of the tuyeres, some FeO is formed, as in a converter at the beginning of blowing. If there is practically no silicon in the iron, as is the case at this stage of the duplex process, this FeO reacts on the carbon and gives wildness. If sufficient silicon is present, it reduces a part of FeO and the silica produced unites with the remainder of FeO to form a ferrous silicate, which goes in the slag.

It is a fact that the final iron shows no wildness at all when the silicon is added in the cupola, but this element suffers a more or less severe loss.

Variations in the silicon content of the final product come from two principal causes:

- (a) Heavy and erratic losses during melting.
- (b) Bad mixing of this element in the bottom part of the

cupola, if it comes from a material rich in silicon added to the charges.

It must be borne in mind that, as the question is presented here, the final iron must have around 3 per cent silicon and a low carbon (say 2.5 per cent), and the first idea is to build up cupola charges with soft or mild steel scrap and ferro-silicon. It soon appears when so doing that factors like the size of the pieces of ferro-silicon lead to very erratic losses.

The oxidation of the silicon can be reduced to a certain extent and made more steady when the precaution is taken to have a strongly acid slag. Such a slag is interesting, not only because it diminishes indirectly the oxidation of silicon by giving FeO the necessary silica to form a ferrous silicate, but also because it prevents a part of the FeO from picking up silica in the lining of the cupola. It has been noted by the writer that when the composition of the slag is studied and conveniently corrected by additions (like in a blast furnace), the loss of silicon is more steady and the life of the lining is increased up to a surprising figure.

Moreover, a strongly acid slag can be obtained very fluid, and this is a valuable feature.

It must be said that the stabilization of silicon losses reached by this means is not efficient enough to allow the practical use of an important part of ferro-silicon in the charges. On the other hand, a strongly acid slag has, of course, no influence upon a better mixing of silicon in the bottom of the cupola. Thus, the problem becomes very intricate, but complementary facts are to be considered.

The author had the opportunity to study, some years ago, the carburization in a cupola of dynamo steel scrap high in silicon. He found that this element lowers the speed of carburization of steel and makes it almost negligible after a certain point. A low carbon cast iron can then be produced with a slow melting and a very good uniformity of silicon content by means of this product. Unfortunately, dynamo steel is not at all a common scrap and no industrial process can be based on its use, but it has been recognized that 3 or 5 per cent of silicon in the scrap is not

necessary to get a low carburization speed; 1 to 1.50 per cent is quite enough, and steel containing this amount is much more available. It is employed in France very extensively by converter steel foundries.

It becomes possible when using this last kind of scrap to increase the final silicon content up to 3 per cent with high silicon pig iron instead of ferro-silicon without fearing to get too high a carbon. Table 2 is the record of a heat performed along this line.

Table 2

Melting capacity of the cupola.....3 tons an hour
Pressure in the wind box.....400 mm. of water

Composition of charges

	Weight Kilograms	Carbon Per Cent	Silicon Per Cent
Pig iron	100	3.00	5.70
Selected steel scrap	150	0.45	1.70
Complete charge	250	1.47	3.30
Coke	35	(14 per cent of metal charge)	

A strongly acid slag was used.

The resulting cast iron had 2.40 per cent carbon and an average of 2.90 per cent silicon with 2.86 and 2.95 per cent as lower and upper limits.

As can be seen, the percentage of scrap in the charges was 60 per cent. The total carburization was 0.93 per cent and the average loss of silicon 0.40 per cent. This last figure is not very high as it corresponds to about 15 per cent of the original amount.

The analysis of the pig iron employed should be noted. Such kind of material is produced in France by at least three important blast furnace companies; it is obviously very interesting in the present case, but during the last few months the production of this type of material has still further progressed. A well-known blast furnace plant has developed, under the advice of the writer, the direct production of pig iron with not more than 2.70 per cent carbon and about 4 per cent silicon. Experience has shown that this pig can be remelted in a cupola without carburizing, and when using it to prepare high test cupola cast iron a



FIG 7—A: GRAPHITE OF VERY GOOD IRON MADE FROM PARTIAL STEEL
MIX—B: GRAPHITE OF CUPOLA LOW CARBON CAST IRON OF
COMPOSITION, CARBON 2.36 PER CENT, SILICON 2.75 PER CENT
—BOTH MICROS X 210

lower percentage of scrap is needed than in the preceding example; 40 to 50 per cent is sufficient.

This is the last stage of the development of the practice in France.

3. *Quality and cost.* It can be said that the mechanical properties of cast iron prepared with the last process indicated are between the properties of semi-steel and those of electric cast iron.

Tensile strength is around 35 kilograms per square millimeter (49,805 lbs. sq. in.) and often more. The metal has a fine graphite due to its low total carbon, and Fig. 7 shows in this respect a substantial difference with a good semi-steel. It also has a fair uniformity of constitution and structure throughout different thicknesses and can compare with electric cast iron from this point of view.

If the cost of this process is now considered, comparison with semi-steel is easy to make. On the one hand, the high silicon pig advocated is slightly more expensive than the low phosphorus pig used in semi-steel (9 per cent more at the present time); on the other hand, more scrap is used, because the average percentage of scrap in semi-steel is around 20 per cent and this counter-balances approximately the extra cost of the pig.

The comparison with electric cast iron is based on the same considerations already developed about this last product and semi-steel.

The writer greatly regrets not being able to publish figures of American prices and French cost data would be out of use here.

If we bear in mind all the preceding descriptions, explanations and comments, we see that this modern method of production of high test cast iron with a cupola, after having been first inspired by observations about the duplex process, has turned, after successive improvements, to resemble the semi-steel process, of which it seems to be a logical improvement. This is probably due to the intervention of many small economic and local or national factors, and anyway, it is a proof of sound industrial interest in France.

The writer does not know if the method is known and em-

ployed in America; he wonders if it can be used, and, at first sight, he cannot see why not, if the necessary alterations are provided.

The main objection against it is that it seems to need rather unusual raw materials. This is not quite the case, because pig iron with 2.70 per cent carbon is not indispensable; it is simply more convenient. If such a product is not available when attempting to adopt the process, some more scrap has only to be added to the charges with eventually up to 10 per cent ferro-silicon without great danger of getting bad results. On the other hand, steel scrap with 1 to 1.75 per cent silicon can easily be found in all railway discards of the world.

Conclusion

If we briefly summarize what has been said in this paper, we see that:

1. A sound basis of production of high test cast iron has been the semi-steel process developed during the war. Fairly good mechanical properties were obtained on test bars, but they were not uniform in any section of a casting, which was a bad feature in the use of such material.

2. The development of the electric furnace in foundries has given place to the single and duplex processes, giving the first real possibility of adopting compositions with low carbon and high silicon, leading not only to better properties but also to a good uniformity and thence to more reliability.

3. The careful study of melting steel scrap in cupolas for the duplex process coupled with the knowledge of the fact that some kinds of scrap have a slow carburization have resulted in the establishment of an interesting cupola process. The final product is as uniform and reliable as if it were produced electrically, it being only slightly less resistant.

It is perhaps possible to further improve cupola low carbon cast iron by taking and treating it in a "jarring" or, better, a "grating"⁶ forehearth. The writer has not yet had the oppor-

⁶ The influence of jarring a liquid cast iron on its mechanical properties has been studied by Irresberger, Deschene and others. More recently, Prof. Girardet has shown that a "girating" motion given to the receiver is much more efficient than simple jarring. See Bulletin of the Association Technique de Fonderie de Paris.

tunity to make tests along this line; he thinks, however, that in such cases the iron would have to be considerably heated in the receiver, and the price of the operation may easily rise too high.

As a matter of fact, the low carbon cupola process is not, technically speaking, an improvement on the duplex; its principal advantages are simplicity and ability to nearly replace the duplex when the operation of an electric furnace is too expensive. If it is complicated and its cost increased, it may rapidly become more possible to adopt the duplex process, which is certainly the best of all at the present time.

The results and details indicated here may appear to be of a low standard if compared to what is often published in the technical press. It is rather easy to get very high figures and splendid results during a test, but when daily practice and routine work are considered, things are not at all as sure and uniform as they appeared to be at first sight.

As already said, the author has only intended to place himself at a strictly practical and industrial point of view. For this reason he has put aside all the more or less extraordinary results he came across during the last year instead of considering them as definite improvements. What he has also intended to point out here is the fact that the French production of high test cast iron has really progressed since the war in the direction indicated by its own previous achievements and a sound technical basis, and that without patented or advertised processes.

The writer here wishes to thank the directors of the American Foundrymen's Association who have indirectly given him the opportunity to give out some particulars about what is done in his country, and he will be very happy if this information is of some advantage to his American colleagues.

Baking Practice for Oil-Sand Cores

By H. L. CAMPBELL,* ANN ARBOR, MICH.

The practice used in baking oil-sand cores may be controlled effectively when all of the changes which take place during the baking period are thoroughly understood. In order to obtain full advantage of the oil binder which is used in the core-sand mixtures, the baking practice must be regulated so as to produce the maximum physical properties in the cores. The chief factors which affect the properties of the finished cores are the time of baking, temperature used, and the atmospheric conditions within the oven.

This discussion on baking practice relates only to cores which are prepared with raw linseed oil. This oil is a complex chemical compound obtained from flaxseed. It is classified as a "drying oil" because it hardens by taking up oxygen from the air. When used in paint and varnish, its property of forming a hard, tenacious coating is well known. The oxidation of linseed oil is accelerated when it is heated in contact with air. At temperatures below 350 degrees Fahr. the hardening of the oil film proceeds relatively slowly. As the temperature is raised from 350 to 450 degrees Fahr., the increased rate of reaction between oil and oxygen is very pronounced. Temperatures above 500 degrees Fahr. destroy the oil film, and will therefore cause a rapid deterioration in the strength of cores bonded with raw linseed oil.

*Associate Professor of Metallurgical Engineering, University of Michigan.
Discussion of this paper begins on page 625.

The constitution and structure of oil-sand cores are not favorable to the rapid heating of the cores from room temperature to the desired baking temperature. The heat conductivity of silica sand is relatively low, and the porous structure of all oil-sand cores retards the conduction of heat through the cores.

In core mixtures containing only linseed oil and sand, very little bond exists between the sand grains before the cores are baked. In order to increase the bond in the sand mixtures, so that various shapes may be readily produced, water is added to the amount of about four per cent of the volume of the sand. In some practice a mineral-oil thinner such as naphtha is used with the linseed oil to aid in distributing the drying oil throughout the sand. The evaporation of moisture and the distillation of volatile oils from the cores may necessitate the use of considerable heat.

A thorough mixing of the components in each batch of core sand is essential to the production of cores having uniform properties. After forming the core-sand mixtures into the desired shapes, the cores are placed in ovens to harden the oil binder and thereby to strengthen the cores.

Changes During the Baking Period

With the aid of special oven equipment, a thorough study was made of the changes which take place during the baking of oil-sand cores. The total time the cores are in the baking oven may be divided into three periods; first, the "heating up" period; second, the "evaporation" period; and third, the "oxidation" period. While the different periods in the total baking time for oil-sand cores may be definitely observed in a small oven with cores of relatively small cross-section, these divisions of the baking period will overlap to some extent in the case of cores having large cross-sections.

During the "heating up" period, the temperature of the cores and core plates is raised from room temperature to the temperature at which moisture or other volatilized products are driven from the cores. The length of this period is dependent upon the temperature of the oven as well as on the rate at which heat is supplied to the oven. In addition to heating the cores, it is neces-

sary to heat all of the iron work which is placed in the oven with the cores.

The permeability of oil-sand cores has been found to be greater after baking than before. This increase in permeability assists in the removal of the volatile constituents from oil-sand cores. Due to the relatively slow conductivity of heat through the cores, and due to the provision for the removal of gases which are generated in the cores during baking, there is no possibility of cores being destroyed when subjected to maximum baking temperatures within the core oven.

The "evaporation" period is the interval during which moisture is removed from the cores. The temperature of the cores remains practically constant during this period. If a core-sand mixture contains a light, mineral oil in addition to moisture, the range of temperature for the "evaporation" period may be extended until the mineral oil has been distilled off. The removal of the volatile products from the cores will be hastened by providing a supply of hot, dry air to the oven during the "evaporation" period.

The "oxidation" period is that part of the total baking time during which the cores become hardened or strengthened. At the end of the "evaporation" period, the cores will be practically as soft as the core-sand mixture from which they were made. The rate of oxidation increases noticeably at temperatures from 350 degrees to 450 degrees Fahr. The presence of oxygen is essential to the hardening process. During the "oxidation" period gaseous products and smoke are given off from the cores. These products, which accompany the oxidation of linseed oil, have a tendency to retard complete oxidation of the oil. Therefore, it is important that these gases be removed from the core oven as rapidly as they are formed.

Effects of Temperature and Time of Baking on the Strength of Cores

In order to establish the most satisfactory baking practice for oil-sand cores, it is necessary to consider the effects of baking temperatures and the time of baking on the properties of cores. During the investigation of this subject, test specimens were pre-

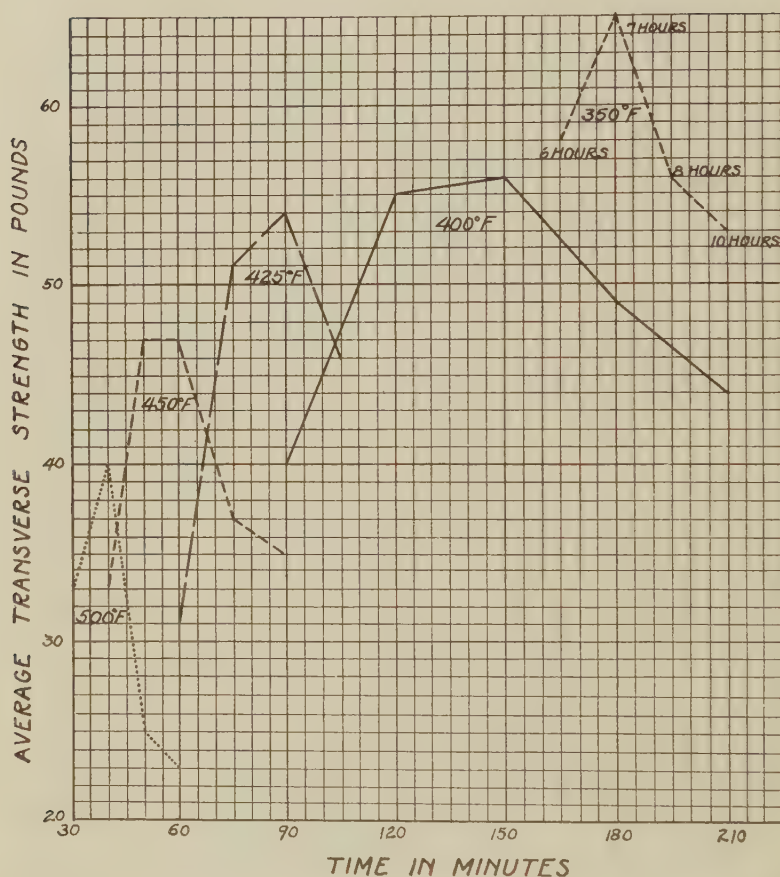


FIG. 1—STRENGTH OF CORES AS AFFECTED BY BAKING TIMES AND TEMPERATURES

pared from definite core-sand mixtures and were tested after baking under controlled conditions. The results of these tests are recorded on the chart in Fig. 1. Transverse test cores one by eight inches were made by the standard method from a mixture containing 60 to 70-mesh silica sand, raw linseed oil to the amount of two per cent of the volume of the sand, and water to the amount of four per cent of the volume of the sand. All of the

cores were baked in an oven which provided for the introduction of some fresh air, and for the removal of some contaminated air. In every test, the oven was heated to the specified temperature before the test specimens were put into it. The length of time required for the oven to reach the desired temperature after the cores were put into the oven was about 30 minutes. The experimental data indicate that the maximum strength of cores which contain a fixed amount of oil binder is dependent on the baking temperatures. It appears that some of the bonding material in oil-sand cores is destroyed at the higher temperatures. Also, the higher the temperature at which the cores are baked, the more limited is the time interval over which high properties can be obtained. As a rule, modern foundry practice demands that cores be baked in the shortest possible time consistent with high strength. From the test results given in Fig. 1, it is apparent that close control of the conditions of core baking is essential to the economic use of linseed oil as a core binder. The information given in Fig. 1 indicates that the most satisfactory periods for baking oil-sand cores one inch by one inch in section are 40 minutes at 500 degrees Fahr., 60 minutes at 450 degrees Fahr., 90 minutes at 425 degrees Fahr., 150 minutes at 400 degrees Fahr., and 7 hours at 350 degrees Fahr.

Core-baking costs may be decreased by using every possible means to facilitate the removal of moisture from the interior of cores, and also to facilitate the reaction of linseed oil with oxygen, which reaction is essential to the hardening of the oil films. The use of perforated core plates will aid in the removal of gases from cores of large size. In some cases it may be possible to hollow out the interiors of large cores, thus leaving relatively thin sections of sand in those portions of the core which come in contact with the molten metal.

Summary of Results

The results of this study of the baking practice for oil-sand cores are summarized in the following statements:

1. Oil-sand cores may be placed directly in core ovens which are maintained at maximum baking temperatures, without injuring the cores.

2. The total baking time for oil-sand cores may be decreased by using a minimum amount of moisture or volatile oils in the core-sand mixtures.

3. The presence of oxygen is essential to the hardening of oil-sand cores.

4. The length of time at which oil-sand cores are kept at maximum baking temperatures has a critical effect on the strength of the cores.

5. The higher the temperature at which oil-sand cores are baked, the more limited is the range of time over which high strengths can be obtained in the cores.

6. The removal of the gaseous products which are given off during the oxidation of linseed oil is essential to the rapid and complete hardening of the cores.

Acknowledgment

The information contained in this report was obtained during an investigation of core-baking practice, which is being conducted at the University of Michigan for the Committee on Industrial Gas Research of the American Gas Association.

Controlling the Atmosphere in Malleable Annealing Ovens

BY W. F. GRAHAM,* MANSFIELD, OHIO

Introduction

The operation of furnaces for annealing malleable iron presents in many aspects a problem peculiar to itself in the art of heat treatment of metals.

The foundryman is faced with maintaining an evenly distributed, controlled temperature in a heating chamber containing a relatively large tonnage of material. The desired change in the character of the carbon content of the iron is influenced not only by the temperature and its distribution, but also by the rate of heat input and the rate of cooling of the charge. Furthermore, the atmosphere of the furnace seems to have a great influence on the decarbonization of the surface of the metal through its bearing on the equilibrium of the iron-carbon-oxygen system. Additional factors entering into the problem are the life of the refractories, destruction of annealing pots by oxidation and fuel consumption. These enter into the cost of the annealing operation in an important way.

In this paper it is attempted to record as a preliminary report a method of firing malleable cast iron annealing furnaces. This method has been applied with a considerable degree of success to two furnaces within the past eighteen months at The Ohio Brass Company. A theoretical discussion of the combus-

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Discussion of this paper begins on page 661.

tion reactions and calculations is avoided and considerations of the conditions of equilibrium are noted only through references to the work of others in this field. The presentation of data is confined to a description of design of apparatus, the method of firing and the results obtained to date.

This method of firing was applied to furnaces of the oven type fired with powdered coal.

Preliminary Investigations

In July, 1927, a new bank of annealing furnaces was put into operation. In designing these furnaces, the furnace engineers provided ample insulation to prevent heat losses. Rather careful studies were made of the firing program and it developed that while it could be made satisfactory from the standpoint of uniformity of temperature and its control, it was almost impossible to approach a neutral atmosphere during the holding period and maintain, at the same time, uniform temperature. The reason for this condition seemed to be that the rate of heat dissipation through the furnace walls was so low that unless the flame was cooled by a considerable air excess, one of two effects would be observed: Either the temperature of the rear of the furnace would be too high or, if the volume of burner gases was reduced,



FIG. 1—FRONT OF FURNACES

there would not be sufficient gas carried forward in the chamber to evenly distribute the heat to the front end.

While the efficiency of these furnaces was satisfactory and the annealed iron met all requirements, it was felt that if it were possible to control the character of the furnace atmosphere, many beneficial effects would accrue. Before two more furnaces were put into operation in May, 1928, it was proposed to return to the furnace chamber some of the waste gases or products of combustion in order to provide greater gas volume, or rather pressure within the furnace.



FIG. 2—BURNER AND CARBURETOR

Equipment

As these furnaces* have already been described by Wishosky¹ no space will be taken to explain their construction but several illustrations are shown to clarify the discussion of the application of this system of combustion. Fig. 1 shows a front view of the first battery of new furnaces installed and Fig. 2 the rear of the furnaces equipped with burners, carburetors, etc., of Grindle design. A section showing flue arrangement and over-all dimensions are given in Fig. 3.

Return of Waste Gases

The return of the waste or flue gases was accomplished in three stages of experimentation.

The first trial was made with gas returned from the flue above the drum on top of the furnace to an opening in about the center of the roof. The results were unsatisfactory, and even disastrous to the pots located immediately under the opening, as apparently a secondary local combustion took place at this point.

It was then decided to return the gases through the car-

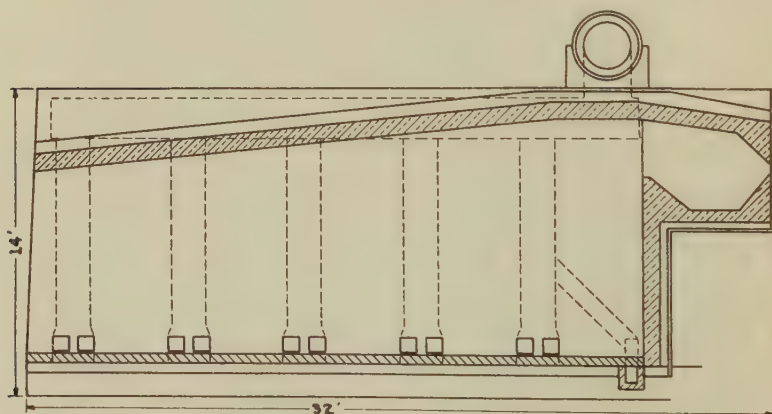


FIG. 3—SECTION OF FURNACE

¹Malleable Annealing Ovens Operate Very Efficiently on Pulverized Coal, Fuels and Furnaces (1928), Vol. 6, No. 1, p. 107.

buretor and burner. Accordingly, a pipe was run from a point on the flue above the exhaust fan to a mixing chamber between the air inlet gate and the carburetor. This pipe was led out of the flue at 4 inches diameter, expanding to 10 inches diameter, as it was thought at the time that it would be necessary to cool the return gas somewhat. A damper above the mixing chamber and one in the stack with the above mentioned constriction controlled the amount of return gas that was mixed with the inlet air.

After a number of trials during several annealing cycles, it was found that an appreciable amount of returned gas could be mixed with the inlet air. The exhaust fan could be shut off during the holding period and the oxygen content of the furnace atmosphere reduced from 8 to 10 per cent to under 1 per cent. The carbon dioxide content was 18 to 20 per cent. The temperature of the furnace was easy to control and there was a very uniform condition of temperature as indicated by the front and back thermocouples. The annealed iron was excellent in quality as indicated by many fractures, showing little "picture-frame" effect.

The above mentioned flue arrangements were made on No. 5 furnace and it will be understood that the return gas firing program applies only to the holding period, although the neutral atmosphere generated would tend to hold between 12 and 24 hours on the cooling period. On account of the favorable operating results obtained on No. 5 furnace, it was decided to equip No. 6 furnace with a somewhat improved return gas system. The principal changes were to eliminate the 4-inch constriction in the return pipe and to provide means to either by-pass the exhaust fan or use it as a venturi exhaust or use it directly. The return gases were withdrawn below the exhaust fan.

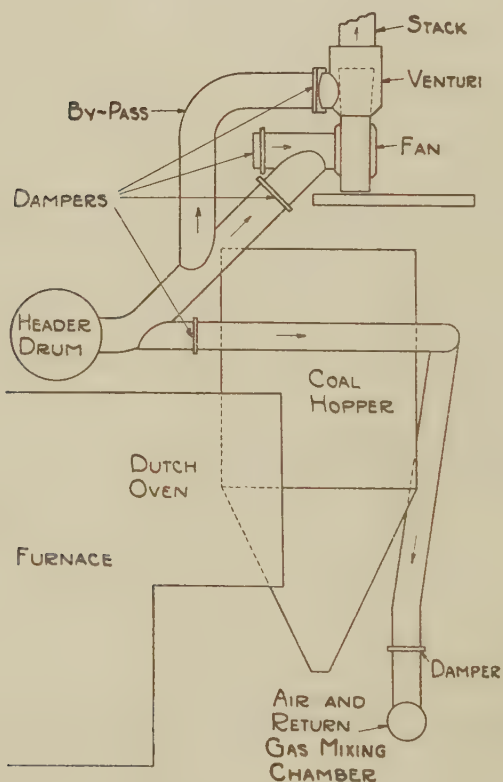
This latter adaptation of the flue system is shown by the drawing, Fig. 4. Two views of the system are shown in Fig. 5 and Fig. 6.

This furnace, No. 6, has been operating with returned flue gas since January, 1929, with very satisfactory results as to control and quality of product.

Discussion of Results

A discussion of the results obtained from this method of firing annealing furnaces might readily fall into two classifications, namely, the principles of combustion involved and a consideration of the effect on the equilibrium of the iron-carbon-oxygen system as it relates to the stability of the surface layer of the ferrite-temper carbon composition.

In regard to the combustion effects, we have found that we



could bring return gas into the mixing chamber at 600 degrees Fahr. and then through the carburetor, producing a temperature of 400 degrees Fahr. immediately below the burner. While this degree of temperature carries an appreciable amount of heat into the burner gases, it is doubtful whether it directly represents a saving in fuel, as the carbon dioxide in the return gas absorbs more heat to bring it to flame temperature than the oxygen in excess air.

Richards² makes the latter point in discussing an article by

²J. W. Richards, *Metallurgical Calculations* (1910), Part 1, pp. 41-44; McGraw-Hill Book Co.



FIG. 5—AIR INLET AND RETURN PIPE

Ellis,³ who describes the Eldred process of combustion. This process, similar in many respects to that described in this paper, was disclosed by Eldred in a United States patent⁴ applied to lime kiln firing in 1902. Haslam and Russell⁵ in a recently published comprehensive treatise on combustion make only brief

³ Carleton Ellis, *Flame Regulation in Chemical and Metallurgical Operations*, Electrochemical Industry (1904), Vol. II, No. 12, pp. 495-498.

⁴ B. E. Eldred, *Method of Calcining Lime, Etc.* U. S. Patent, No. 692,257, Feb. 4, 1902.

⁵ R. T. Haslam and R. P. Russell, *Fuels and Their Combustion* (1926), p. 292; McGraw-Hill Book Co.



FIG. 6—FAN, BY-PASS AND STACK

mention of firing with return flue gases and state that it has only special applications. While it may not be possible to justify this method from the standpoint of the theoretical heat balance, at least we believe that we have uncovered enough practical benefits in firing control to warrant further application and investigation.

We are not yet able to report figures which would give accurate comparisons of coal ratios, but it would appear that the coal consumption in this method would be low, due to uniformity of temperature and the ease of control. Data as to pot life are not yet available, although visual examination indicates less formation of scale. In this connection, it may be said that the character of the furnace atmosphere has been determined by the eye, checking with numerous intermittent gas analyses, as carbon dioxide and carbon monoxide meters have not yet been installed. No attempt has been made to carry more than a fraction of a per cent of carbon monoxide.

The stability of the surface and the surface layer of the malleable cast iron during the annealing cycle has received the attention of a number of competent investigators in recent years. The formation of scale on the castings and a "picture-frame" fracture either ferritic or pearlitic, are effects of conditions, more often than not, incapable of interpretation by the practical foundryman.

Some writers seem to place considerable importance on the effect of the analysis of the iron, for example, Evans and Peace.⁶ Others, such as Schwartz⁷ who summarized before this Association last year the work of Schenck and others, explain the reactions on a physical-chemical basis through a consideration of the equilibrium of the iron-carbon-oxygen system.

If the latter explanation is true, and the writer believes it to be, then a control of gas composition and concentration together with a control of gas pressures for a given temperature within the furnace chamber should determine the direction of the reac-

⁶ W. T. Evans and A. E. Peace, *Malleable Castings*, Foundry Trade Journal (1928), Vol. 38, No. 619, p. 480.

⁷ H. A. Schwartz, *Oxidation Phenomena During the Annealing of Malleable Cast Iron*, Trans. American Foundrymen's Association (1928), Vol. XXXVI, pp. 385-396.

tion in the iron-carbon-oxygen system. Hayes⁸ and others have investigated experimentally the stability of the system and from these data, this or other methods of firing control may be eventually established on a sound theoretical basis.

Our study of fractures of iron from annealing cycles operating on return gas indicates that a marked effect has taken place, and it is reasonable to assume that it can be explained by a definite condition of equilibrium between the constituents of the iron and the furnace atmosphere if all data were available. It is hoped at some future time that it will be possible to report further progress in the study of this subject.

Acknowledgment

The writer desires to acknowledge the co-operation and assistance of a number of members of the operating and technical staffs of The Ohio Brass Company in this investigation, particularly Messrs. J. E. Warrack and E. J. Ash.

⁸Anson Hayes, *The Metastable Nature of Iron Carbide* (1927), Bull. No. 83, Engineering Experiment Station, Iowa State College.

Practical Melting with Electric Arc Furnace in General Jobbing Brass Foundry—With Special Emphasis on Operation, Maintenance and Cost

BY J. B. MEIER,* NEWARK, N. J.

Introduction

In this paper we shall endeavor to present the material under three divisions, namely, operation, maintenance, and cost.

While we realize that some of the factors may enter into more than one of these groups, at the same time we feel it will more generally meet the need of those interested in these individual phases if we at least attempt to concentrate on one of these items at a time.

In order to be of any definite value to any persons interested in a comparison of this method of melting with any other method of melting, or even to compare similar installations with results obtained during the writer's experience, it is of prime importance to know as much about the conditions under which these furnaces operated as is possible.

*Vice-President, F. and H. Foundry Company.

Discussion of this paper begins on page 651.

I. General Description of Work Handled

The work handled by our foundry comes under the general jobbing class. No work is produced for its own consumption. This naturally does not lend itself so easily to any great advance planning, as it is difficult to determine what work will be required much further than three to five days in advance. And even then the schedule must frequently be broken into to meet the special needs of customers. About 75 per cent of the work is what might be termed semi-production, namely, machine work of from one to ten days' duration. The balance comes under general jobbing. The majority of the castings are pressure casting of about $\frac{3}{8}$ of an inch section and in some cases as thin as $\frac{1}{16}$ of an inch. Very few reach $\frac{1}{8}$ of an inch and none over, unless the design requires a boss or thread. These sections have been introduced without exception during the past twelve months; previous to this time the sections were $\frac{1}{2}$ of an inch greater or $\frac{1}{8}$ of an inch. This has increased the difficulties of pouring and requires a temperature of 2200 degrees Fahr. where we formerly required 2100 degrees Fahr. The greater portion of the castings are plumbing supply castings (but not what is known as pipe fittings), practically all of which are cored work. During the year 1928 we melted in electric furnaces 40 per cent composition, 48 per cent brass, and 12 per cent high lead bearings; or a total of a little over 810 tons. One hundred additional tons were melted in oil furnaces. So far we have melted about two million pounds in the electric furnaces.

(a) Plan of Shop

The shop layout is such that the metal comes in at the rear of the shop; is weighed in charges usually 400 pounds and conveyed to the furnaces in the next section by mono-rail, from which 90 per cent is distributed forward to the main molding floor.

The sketch in Fig. 1 shows the position and general spacing of the units involved in the melting department. The space occupied by the two 350-pound capacity Detroit Electric Furnaces is about 20 feet by 20 feet. The transformers and high voltage switches are located in a vault outside the main foundry, as

the city ordinances require a vault and the furnace people recommend an outdoor installation for the transformers. Attention is drawn to the location of the operating ends of the furnaces and the location of the meters, enabling one operator to take care of two furnaces with a minimum of movement. In fact, it is the writer's opinion that it would be very difficult for one operator to take care of two furnaces if they were not placed with the operating ends together.

(b) *Type Metal Used*

The 85 $\frac{3}{4}$ mixture is composed on the average of 2 parts ingots, one part scrap and 3 parts gates.

The brass is composed of 1 part ingots, 2 parts scrap and 3 parts our own gates.

It may be well to mention here that the word *scrap* covers a big field.

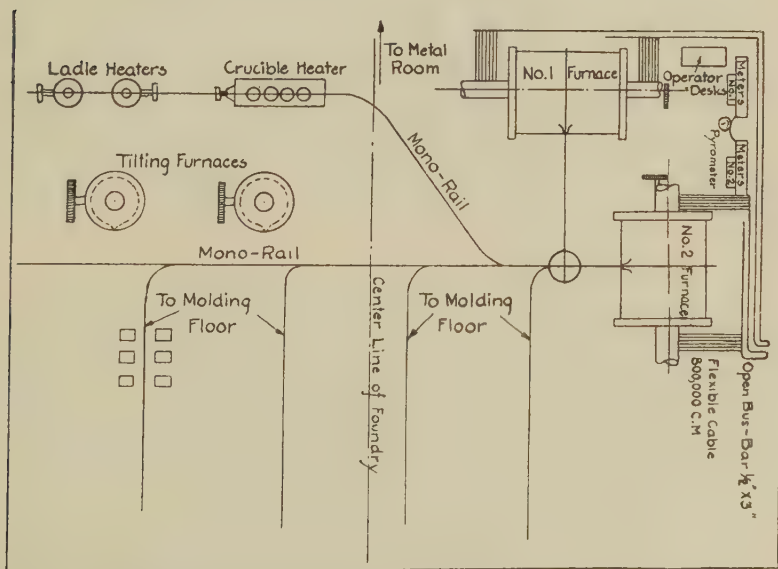


FIG. 1—SKETCH OUTLINING THE POSITIONS OF THE VARIOUS UNITS LOCATED IN THE MELTING DEPARTMENT OF THE FOUNDRY

2. Operation of Furnaces

There are several features necessary to observe if one is to obtain satisfactory results from this type of furnace. We consider the following to be in about their relative order of importance:

(a) Charging and Pouring

Complete pouring and charging in the minimum time possible is essential. Naturally, the charging is more important than the pouring, for in pouring the furnace does not suffer nearly as rapid a loss of heat as during charging, for in the latter case the door is open, and the heat loss is more rapid. We have found it is necessary to add about 1 kw. for every two minutes the furnace is open above the initial five-minute period, in order to get the same temperature, other conditions being equal. In order to keep this time down to a minimum, it has been found economical to provide the operator with a helper during the charging period. When ingots or heavy pieces are used it is necessary to withdraw the carbons, but with all lighter material it has been found advantageous to allow the carbons to stay in.

We have found it more economical to charge the first heat the previous evening, only taking the precaution to try the arc to be sure no short circuit will necessitate opening the furnace in the morning. This does not apply to Mondays or holidays, however.

(b) Rocking of Furnace

The next item of importance is the rocking of the furnace. We start rocking the furnace at from 5 to 15 kw. input, usually at 10 kw., coming to a maximum at 35 to 40 kw. It has been our experience that failure to rock early enough or efficiently, namely, full rock as quickly as possible, renders it extremely difficult to get the metal hot enough, as well as increasing the kw. input in proportion.

(c) Maintenance of Proper Arc

The next item is to maintain the proper arc. This is only accomplished by constantly keeping an eye on the meter, as the

arc is manually controlled. Failure to do this, means loss of time and cold metal. It is practically impossible to get good results from these furnaces by methods which were good enough for oil or coke. Things happen too quickly, and the man operating this furnace must watch his meter or the day's check up will tell the sad story.

(d) Accurate Records

The operator is required to mark the time of starting to charge, time of starting arc, time or kw. starting to rock, time arc is off, quantity of metal as well as the type of metal and temperature. With all this writing to do, as well as the pouring, charging, etc., it keeps a man busy if he intends to get out fifteen 400-pound heats in nine hours. By carefully checking records it is quite easy to determine in the office just where the system is falling down. If the operator is careless in his records it is practically impossible to tell where the fault lies. But because it is possible as well as practical to get accurate records (this being one of the chief assets of the electric furnace), for each day in about fifteen minutes, a complete check-up can be made on the kw. per ton, and the per cent efficiency for that day. A word or two to the operator will usually bring him back to normal or quickly disclose the source of trouble. It may be noted here that any unusual occurrence, such as carbon broken, metal not on hand, or laxness in helpers bringing crucibles, is marked on report.

(e) Slag

Another cause of inefficiency which is usually only prevalent when using particularly dirty scrap, is the slag building up in the furnace. While with ingots or clean metal this is negligent, it can under unfavorable circumstances cause almost as much trouble as insufficient rocking. It will also, if allowed to build up, work a severe handicap on the lining as it causes the metal to lay higher in the furnace, throwing more heat on the upper half, and allowing the lining to be rapidly melted away. It, of course, makes just that much more material to be heated up, with its consequent losses.

(f) Quantity Charged

The amount of metal which can be charged at one time varies considerably. All ingots, with a clean furnace, will permit 500 pounds. With about half ingots and balance scrap and gates, it is not difficult to charge 350 pounds. Turnings, skimmings, etc., work best at 300 pounds or less. Copper cable is particularly annoying, and 100 pounds in a 300-pound charge will often cause a short circuit, as it is difficult to keep it from touching both electrodes, and its high conductivity permits a great amount of current to pass.

(g) Varying Mixtures

Changing from various types of metal is not as easy as with oil or coke. If the type of metal is of a lower grade, such as yellow brass is with respect to 85%, it can be done quite readily. But if it is the desire to follow a heat of aluminum bronze or nickel brass with an 85% or 88-10-2, it requires a very thorough slagging of the furnace, and even then we find it safer to run a straight brass heat next if it is possible. For if we don't, we usually find traces of aluminum in the following heat, and it has not been found as easy to change mixes for this reason. However, as we have two furnaces running most of the time, this is not as great a problem as it would be with one furnace. At the same time when it has to be done it costs an additional 10 to 15 cents for slagging, besides there is always the danger of the operator doing it carelessly and making an undue wear on the lining.

(h) Operating Labor

The operation of the furnaces does not require any special skill, but it does require constant attention to the details mentioned. The operator very quickly becomes familiar with the quickest and best way to charge, and changes his method to suit the type of metal he is handling. With light material the furnace can be successfully charged without removing the carbons, but with ingots or heavy pieces it is necessary to remove them. Breakage of carbons very soon becomes negligible and with it the usually accompanying feature of burning out the

port blocks. So that very little reaming of the holes is necessary, which, when necessary and not done, causes more carbons to be broken, which forms a very vicious cycle.

In the beginning, pouring also causes several charges to go on the floor, but in a short while the operator can pour with quite a degree of accuracy, both as to *place* and *quantity*. The really greatest task is to get the operator to keep accurate records. Naturally, the type of labor melting metal is not particularly given to the arts and writing is not his by nature. It is only by using his poorly kept records as a lever to place all the blame on him that he finds in self-defense he must keep them accurate. It is often interesting as well as amusing to see how economical they are with a pencil. Our present operator never writes a single unnecessary or duplicate item. If he has two sheets he only puts the date on one, never the month or year; the office can do that, he told me once. And in writing the time, he never writes a zero if he can be understood without it, such as 3:05, he writes 3-5. Knowing the circumstances, however, we can always decipher what he means.

3. *Maintenance and Repairs*

The maintenance of the furnaces and accessories does not entail any more care than oil fired furnaces, although certain things must be done regularly. Once a week we have a special man oil and grease the moving parts as well as the motors.

(a) *Cables*

The present greatest source of expense aside from the linings are the cables. We have not been able to get the results we feel should be obtained. The design is such that it simply seems impossible to keep the cables from breaking near the furnace, where a very narrow bend is located. We get about a year's service from these cables by reversing the ends, but often they cause trouble when they get old by the strands breaking, leaving the remaining good ones to be greatly overloaded. It seems to the writer that the design could be improved so that these cables last indefinitely.

(b) Clamps

The clamps would never need renewing if the operator would never forget. But like most of us, he does forget; and he only forgets for about one second and the damage is done. During the past year, however, we only replaced one clamp so that this trouble seems negligible.

(c) Motors

Due to the reversing mechanism, it is possible to have the rocking motor on a single phase with two phase power, if the operator is careless or inexperienced. We have found that if a man burns out a motor he remembers thereafter, but since we have only had the same two operators, we have not burned out any motors since the first two in the beginning.

(d) Linings

By far the most important feature is the linings. In the beginning we experimented with various kinds of linings. We

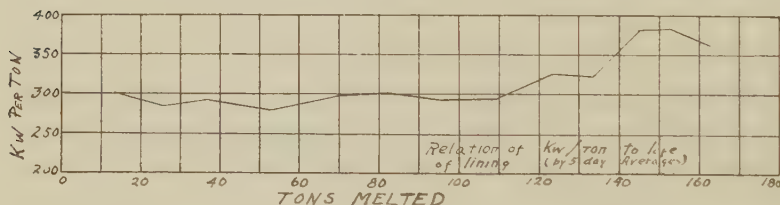


FIG. 2—RELATION Kw/TON TO LIFE OF LINING (BY 5-DAY INTERVALS)

tried several linings with a carborundum base and a glance at the chart of Fig. 2 will show a rapid rise in May, June and July, 1927. This was entirely due to these types of linings. It appears to the writer that the insulating material could not stand up under the high conductivity of the lining and consequently was rapidly broke down, allowing great heat loss through the shell. The outside temperature of the shell measuring 550 degrees Fahr. whereas with the present linings of a fire brick material shows about 200 degrees Fahr., increasing with the age of the lining. Contrary to general practice, we do not renew our lin-

ings by the number of heats or visual examination, but by the per cent of efficiency of melting. We obtain this per cent efficiency by adopting a set of standards which correspond to the manufacturers' guarantees. These are 300 kw. per ton of composition, 275 kw. per ton brass, and 240 kw. per ton for our own leaded bronzes. These figures we use as including all input, whether for relining, slagging, or any other purpose.

However, each day we calculate the standard kw. required for the metal melted that day, allowing 25 kw. extra for Mondays or days after holidays. When the lining reaches a point where conditions are such that 15 heats (400 pounds) should have been taken out in $9\frac{1}{2}$ hours and, cannot, at the same time show an efficiency of 10 per cent above standard, the lining is invariably in such a physical condition as to warrant its renewal. We have not found it profitable to patch any large areas, in general, and between the cost of the patching material, the loss in production, and the increased power consumption, we find the old lining will very quickly eat its head off. Under these conditions, we often remove linings which appear good, but are so thin the heat losses are far more costly than the lining.

A new lining installed costs us about \$65.00. It is put in and run in with the utmost care, and *not* by the operator, as he is melting and could not do it properly if he wanted to. An old lining would cost us in power, if allowed to run two weeks, about \$20.00 more for 150 heats, whereas it would give us a saving in linings of only about \$14.00, besides the loss in production. The experience that we had proves that 10 per cent of the power cost will not cover the power loss for most linings over that period, so say nothing of patching labor and material.

Since we also vary our charges considerably we do not rate our linings by heats, but by tons. Reference to Table 1 will give this tonnage, which is a little over eight hundred 400-pound heats for 1928.

(e) Patching

As explained previously, we do very little patching, our expenses being about \$50 for this item for the year. In the first place, we have never found a satisfactory hot patch, and so do only what hot patching is unavoidable. If the lining is in such a condition that a major patch is warranted, we do it cold, and very thoroughly, chipping the glaze all off and dove-tailing it under the old lining, ramming it in as dry and as hard as possible. We then turn the furnace so that the patch is down and glaze it thoroughly. If done carefully, and not too large, it will last the life of the lining, but it takes two to three hours, besides the power to glaze it.

(f) Transformers

Initially we had two 100 kw. transformers. While there is little doubt that they are sufficient for operating the furnaces, at the same time they permit of much overloading and it has been our experience that where an operator can speed things up and at the same time not work any harder, he will usually do it. As a result, the furnaces often pull 130 kw. and almost always 120 kw. In addition, when melting light scrap, copper or turnings, they also permit excessive short circuits, which in our case, resulted in the breakdown of a transformer right at the busiest season. Considering the slight additional cost of a larger transformer, it surely seemed like a good investment to get a 125 or 150 kw. transformer. So in replacing the burnt out one we put in a 150 kw. This not only gives us a slightly greater speed but eliminates all possibility of overloading. We had the oil inspected at the end of a year's service and found it could not be brought up to test, requiring new oil. The power company testing the oil recommended filtering every six months, which can be done on a Saturday afternoon.

(g) Oil Switches

In the beginning we had considerable trouble with the remote control switches, but since they have been properly adjusted

they require little attention, except to tighten up the nuts about once a month, which seem to shake loose due to the pounding of the arm as the solenoid slams it in.

(h) Shell

The lining shell needs attention at each relining as there always seems to be some bolts which break off and must be re-drilled and tapped. This causes about two hour's time at every relining, which could be saved if the design could be improved.

(i) Smoke

Due to the constant reduction in metal sections in castings, higher and higher pouring temperatures are required. Most of our work is poured at 2150 degrees Fahr and much at 2250 degrees Fahr. The brasses especially, smoke so furiously that it was necessary to remove the fumes. This proved less expensive than anticipated by making use of our coke pit stack. By building a hood over each furnace and running 12-inch sheet iron pipe to the stack about 10 feet away, we now remove about 95 per cent of the smoke from the foundry at once. In relining the furnaces, it is only necessary to loosen a few bolts and remove the hood, so that we can lift the shell on to the floor with a hoist.

4. Cost

In order to best understand the cost of melting it has been subdivided in its various parts.

(a) Electric Power

The item of first importance is the electric power. This item presents a little difficulty in analyzing because of its complicated nature. The power is purchased as primary power, the rate being independent of the connected load, but varying with the maximum demand of any 5-minute period during the day. This works a considerable handicap on the use of two furnaces, where a large jump in the demand occurs as soon as the second

furnace is operated for five minutes. In addition, the power charge varies with the total consumption, as shown by the data on chart of Fig. 4. These curves in Fig. 4 are plotted against standard efficiency for various numbers of heats, for different demand charges.

From experience we know we can get sixteen heats in $9\frac{1}{2}$ hours with one furnace. We also know the first heat takes about 35 kw. more than those after the fourth. The second heat takes about 15 kw. more and the third about 5 kw. Therefore, to take out four or five heats is not very efficient. To determine just where the second furnace should come in we plotted the curves of Fig. 4. These curves show that if we take sixteen heats our power cost is about \$0.0268 per kw. hour, if we take seventeen heats by running one in the second furnace, our rate immediately jumps to \$0.0320 per kw. hour. We find it more economical to run the oil furnaces up to about twenty-one to twenty-two heats, which is shown by the shaded area.

From a study of the chart of Fig. 3 we find that the cost per kw. varies closely with the tons melted per month. Some explanation of these curves will make this more clear. In the beginning of 1927 the cost per kw. hour decreased until May where it jumped up until the end of July. This radical jump was due to the installation of two silicon-carbide base linings, which caused enormous heat loss and consequent power consumption. Upon removal of these linings the cost dropped, rising gradually as the tonnage dropped, reaching a maximum at February, 1928. From then on it maintained a fair level with a gradual slope, due in part to a change in the casting wall thickness, and introduction of nickel brasses, both requiring higher temperatures than previously. The cost per kw. hour has increased in 1928 over 1927 by increased demand charges due to the installation of a larger transformer and about 40 hp. additional motor load, making a larger demand charge with a smaller increase in power consumed. Reference to Table 1 will show the average kw. per

ton; the average cost per kw. and the product of the two, which is the power cost per ton.

(b) Labor

The next item is the labor. The labor on the electric furnace required a reliable man of probably a higher order than for oil,

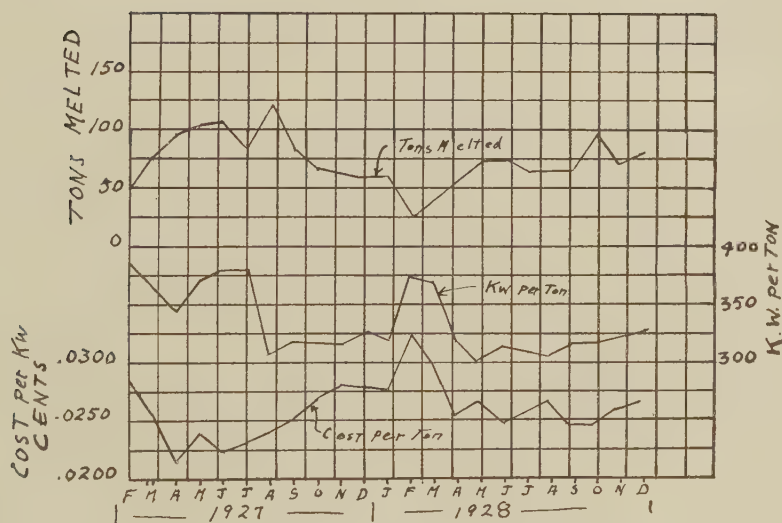


FIG. 3—TONS MELTED, Kw PER TON AND COST DATE

for a careless man can ruin a transformer costing about \$1,000 very quickly. But the work is so much less laborious and practically no heat, that a higher grade man can easily be induced to stay on the job. We have had the same furnace men ever since

the installation, being negroes, used on the oil furnaces previously used. With oil we always had a high turnover and much absence and tardiness. On the electrics this is practically nil. To melt with oil our labor cost us on the average of \$3.75 per ton. Compare this with \$2.30 in Table 1. Further efficiency is obtained

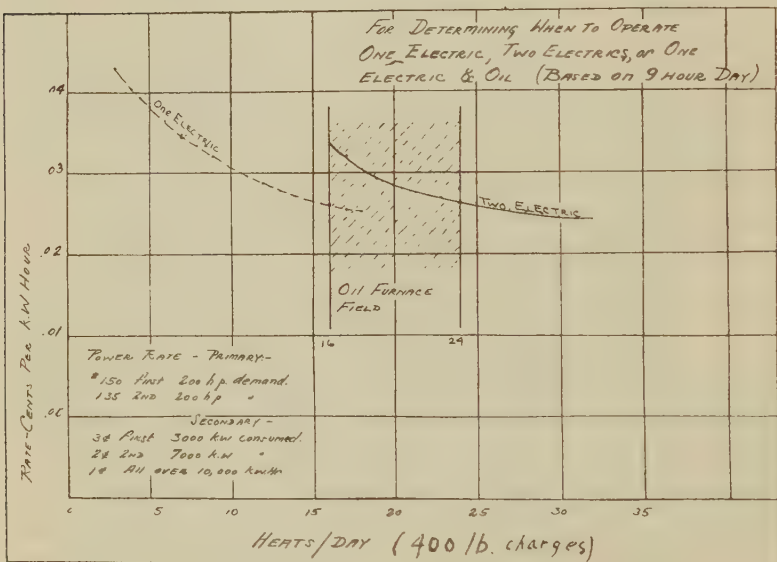


FIG. 4

CHART DEVELOPED TO DETERMINE WHEN TO OPERATE FURNACES

by paying a bonus to the operator as follows: Fifty cents for fourteen heats, 75 cents for fifteen heats, \$1.00 for sixteen heats. This urges the operator to get out the maximum amount of metal. The bonus is only paid if it is within 9½ hours. For him to succeed he must run the furnaces efficiently.

(c) Fuel Oil

This item averaged about fifteen gallons per ton metal melted for 1928. On test, this figure was only $7\frac{1}{2}$ gallons per ton, but a fair production rate would be 10 gallons per ton. But owing to carelessness in cutting down the oil to the proper mixture, or allowing it on too long, it is about 50 per cent higher than it should be. Nevertheless, due to the fact that this item can only be checked once a month, it does not lend itself to close check, which is one of the chief advantages of electric melting, for every day the day's efficiency can be determined and pressure brought to bear at once to correct it.

(d) Electrodes

The next item is electrodes. For the past year, this averaged $4\frac{1}{2}$ pounds per ton melted. The type of metal and carelessness on the operators' part are the chief factors involved. Rocking when improperly charged causes breakage. Improper condition of the porthole also causes breakage. Clamps which leak contribute to the rapid consumption of electrodes. Improper arcing also burns up electrodes unnecessarily. With a conscientious operator it should not be difficult to bring it down to four pounds per ton, for we have done it several months.

(e) Crucibles

Reference to Fig. 5 will demonstrate the ladles used. Considerable economy in fuel oil, maintenance of temperature and crucibles are obtained by this type of pouring. The average number of heats from the crucibles was 225. Some have gone to 400, and many 350. The chief loss is due to carelessness in cleaning the crucibles after pouring, as frequently a hole is poked right through and not patched. The metal then gets in back of the crucible and quickly cracks it or makes it too heavy to carry.

Considerable advantage is derived from this ladle through greater heat holding qualities, very little drop in temperature occurring.

(f) Linings

Reference to the chart of Fig. 2 will show the effect of the lining life on the kw. per ton. It can be readily seen that up to about 100 tons the slope is nearly level, after which it rapidly changes, due to the fact that not only does it take more power, but less heats are taken out because it takes more time, which

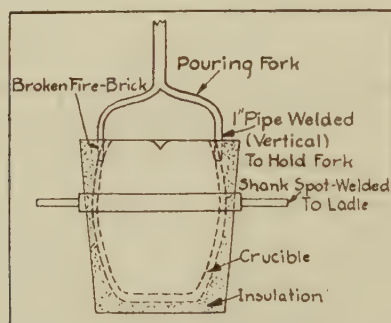


FIG. 5—TYPE OF CRUCIBLE LADLE USED

exaggerates the average kw. per ton still more. The tonnage per lining averaged 162 tons, which is about eight hundred 400-pound heats.

(g) Patching Material and Supplies

The chief cost involved here besides the patching material is the replacement of cables. It seems some improvement could be made in this line, as it requires replacement of cables about once a year, due to the bending action, which breaks the strands. Reference to Table 1 gives this cost.

Table 1

SUMMARY OF MELTING COSTS PER TON MELTED

Electric power.....	321 kw. @ \$0.0259	= \$ 8.35
Wages.....	@ 60 cents hour	= 2.30
Fuel oil for ladles.....	14.9 gallons @ 7 cents	= 1.04
Electrodes.....	4½ lb. @ 0.22 60/100	= 1.00
Crucibles.....	.70—22½ tons	= 0.29
Linings.....	@ 162 tons/lining	= 0.39
Patching and supplies.....		= 0.17
Sub-Total		\$13.54
Metal loss, 2.4%.....	@ 12 cents per lb.	5.76
Semi-Total		\$19.30
Unforeseen: Transformer burnt out.....		1.20
Grand Total		\$20.50

Table 2

OVERHEAD COSTS ON MELTING PER TON MELTED

Supervision	\$0.20
Interest on investment.....	0.65
Depreciation (10 years).....	1.08
Taxes \$3.78/\$100.....	0.25*
Total	\$2.18

*Taxed at 60% of value.

(h) Metal Loss

Every one is usually interested in this item, but it is impossible to compare it accurately, even in the same shop, if scrap is used, because there is such a large variation in loss in different scrap. In the writer's own experience brass tubing contained 18 per cent scale alone, and lead-covered cable contained 8 per cent cotton insulation. It is therefore extremely difficult to convey to outsiders any idea of the loss. However, the only comparison which can guide to some extent is the metal loss in the same foundry under oil and under electric melting. The average of the three previous years of operation under fuel oil was 5.7 per cent. The past year under 85 per cent electric melting and 15

per cent oil melting the loss was 2.4 per cent. Naturally, this is no small item, and is one of the chief justifications for electric melting.

Table 1. Totaling these various items we find a cost of \$13.54, exclusive of metal cost, compared with a similar cost of \$17.50 under fuel oil. If we charge the entire cost of the new transformer in one year it would be \$14.74, against \$17.50, or, roughly, \$2.75 net saving in operating cost. Including the metal loss it is \$20.50, against \$31.10, for fuel oil, or a net saving of \$10.60, or 34 per cent less than fuel oil. While it is reasonable to assume that the fuel oil costs are too high, at the same time it must be remembered that both methods have had the same supervision, but that one lends itself more readily to supervision than the other. It can also be argued that anyone attaining greater efficiency with oil should have the personnel available to get still better efficiency with electric melting.

In Table 2 is given a brief estimate of the general costs which properly could be charged to melting.

Safety Considerations for Foundries

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Safety in the foundry as in other manufacturing operation can only be achieved by the combined effort of all the personnel to be safe. This desire for safety accomplishment must start with the managing head—whatever may be his title, owner, president, manager, etc. The measure of success obtained will be in direct ratio to the degree that this “Will for Safety” is projected down through the organization to the very youngest apprentice or tag boy.

Humanitarian and Economic Conditions Both Improved by Safety Program

It would seem that the possession by managing heads of the usual humanitarian instincts is not enough. They must also be fully convinced that accidental injuries in the course of employment are an unjustifiable waste and one of the most important “intangibles” in high production costs.

This last realization is usually necessary to cause due consideration to be given to the unpleasant effects of injuries and the worthwhile possibilities of the prevention of injuries.

*Manager, Casualty Dept., American Steel Foundries.
Discussion of this paper begins on page 624.

Where Safety Planning Begins

The prevention of accidents and consequent injuries should begin with the planning and layout of the foundry buildings, and yard, the installation of the equipment, the laying out of the various molding floors, the paths by which the production will travel through the various departments such as cleaning and shipping departments, and other operations which will be mentioned later.

It is probably safe to say that the majority of foundry buildings now in use are not ideal with respect to safety under present-day conditions if they ever were, and it is very easy in the usual rush of providing new buildings or a new foundry to overlook a number of very essential features that would be aids to safe operations. These deficiencies, old and new, usually mean that management makes the very best readjustment possible from a production point of view, but too often safety considerations are neglected and put off until a more convenient time. When this is done it is a serious mistake because production without safety is poor economics.

New Equipment Should be Considered from Safety Viewpoint

The purchase and installation of new equipment should always be given careful and continued study to foresee and prevent injuries, especially during the time the equipment is being installed, then "broken in" and while the operating workmen are getting acquainted with its operation. Most new equipment is purchased, but the work of installation is frequently done by the foundry mechanical department, with the result that frequently work is attempted that is practically new to the whole force from the plant engineer down to the laborers. All hands are so interested in the work in hand that they frequently overlook simple but necessary precautions that men take who are regularly engaged in work of that character. Excavations will be made without proper shoring, building columns will be undermined without adequate supports and structural materials are hoisted with inadequate lifting devices. The whole procedure is a series of gambles with fate; with lives and limbs for pawns. At such a time the manager, who thinks there are other and more important duties

than being continuously on the job, and acting as safety supervisor, is likely to experience a sad awakening.

When a new piece of equipment is ready for operation, although it may apparently be fully guarded, supervisors who are watching its performances in production should be especially watchful to see that it is being operated safely. Workmen may want to remove and lay aside guards giving as excuses that adjustments have to be made and replacing guards take too long. Then guards furnished with the equipment may not work properly in the new service or location.

In the case of new molding units such as jarring machines, sand slingers, etc., when first placed in operation, care must be exercised to see that dangerous situations do not develop in serving the unit with sand, facing, flasks, etc., and in routing finished molds away from the units to the pouring floor. The workmen in trying to get production in spite of imperfection in the service of supplies may use too much haste, or may try to use too much physical force and get injured.

The dangerous possibilities inherent in a new piece of equipment or in its location usually are not all discovered at once. These possibilities for injury are not anticipated by a close study and thus prevented, but are allowed to become known through the medium of tragic injuries to the workmen.

Workmen Can Suggest Improvements

Dangerous imperfections in operations and practice usually are soon known to the workmen, but frequently nothing is said by them because they do not want to be considered as alarmists or kickers. They would readily tell what they have observed and know if asked by a foreman.

Avoiding Accidents by Luck Creates Bad Situation

The fact that injuries are being avoided by dexterity or "luck" is a bad situation and should not be tolerated by management. That this is many times the situation is borne out by the study made by the Travelers Insurance Company of Hartford,¹

¹ Heinrich, H. W., *The Foundation of a Major Injury*. Mr. Heinrich is Assistant Superintendent Engineering and Inspection Division, The Travelers' Insurance Company.

Connecticut, as set forth in the "Travelers Standards of January, 1929," wherein it is shown from an analysis of 50,000 injuries that for each major injury, there are 29 minor injuries and not less than 300 accidents that do not cause any injury, but which have all the inherent potentiabilities that the one accident had that caused the one major injury.

While these facts have probably never before been stated so clearly as is done in the article just referred to; yet unconsciously most workmen have known that the ratio of injuries to accidents was small and have probably lulled their fears with the thought that the law of averages as they dimly understand its workings would enable them to escape injury "if they were lucky." Such a mode of thinking by workmen may be excused or condoned, but such thinking by management is inexcusable.

In a less enlightened day, workmen facing this unknown 1-29-300 hazard sometimes developed considerable pride in their supposed skill in escaping the dangers of their particular craft or calling, feeling that such escape entitled them to be considered master workmen; when, as a matter of fact, it was not always the best workman who escaped.

Consider what this mode of thinking has cost—there was the major injury with its suffering, loss of earning power, and loss of production. Then there was the tremendous loss of productions occasioned by the other fellows working with one eye on production and the other eye the "Jack be nimble, Jack be quick" proposition, if they were to escape injury.

The foundry that has operations or processes that require men to be constantly flirting with danger while in the course of their employment had better correct the situation before casualty compensation costs wrecks the financial structure.

A Clean and Orderly Shop Prevents Accidents and Reduces Costs

The one thing that will do more to reduce accidents with the least expenditure of money is to clean up the shop, then keep it clean. This fact has been proven so often that it cannot be successfully questioned as it once was.

A clean shop reduces foundry costs also.

An old-time foundry superintendent when asked why he did not clean up his shop, said that "a clean foundry was a foundry without enough work to do." Most foundrymen know better now, but there are still a few of this tribe who should take a course in "good housekeeping."

When we refer to a clean shop that means every department clean. If you are short of room anywhere, clean things up a bit cleaner, then you have at least some of the room needed plus greater ease in working, and at the same time you will reduce accidents.

After things have been cleaned up for a time, the suggestion that a concrete walk down through the foundry and out to the office or a concrete floor in the cleaning room, or a few flowers along the walk from the gate to the shop won't sound a bit foolish or impossible.

State Compensation Laws

Practically every foundry is today operating under some state compensation law, and that means the payment of compensation for injuries arising out of and in the course of employment. Frequently it also means payment for physical conditions, such as hernia, lame back, etc., that did not arise, neither were they received in the course of employment.

What a relief and satisfaction it would be if all our injury cases were clean cut disabilities that came under the specific schedules of the compensation act, with known or readily calculated amounts of compensation so that we could say authoritatively to the injured workman, you will be paid so much and no more. Contrast this with our many present cases, coming under the various indefinite classes that may require that compensation be paid for years and, in some instances, for the life of the injured. All of these last type of cases invite the potentially dishonest workmen to see just how long they can extract compensation and refrain from work; as a result of which paraphrasing the Psalmist, we are tempted to exclaim: "In my haste

I said all men are (liars) malingerers." However, workmen's compensation is here to stay, so we should make the best uses possible of this "instrument of adversity," and we believe it can be made an important aid to safety.

Few Foundries Are Large Enough to Carry Their Own Casualty Insurance Risks

Comparatively few foundries are large enough to warrant their carrying their own casualty insurance risk, with the result that casualty insurance is bought from either a state fund, a mutual company, or a regular casualty insurance company. The premium paid usually reflects the accident experience of the insured with adjustment of premium rates from time to time as a result of that experience. Insurance companies offer their clients valuable services through their inspection departments, looking to the elimination of hazards, the reduction of accidents in the foundry, all of which is helpful. There is, however, a tendency to pay the premium and then let the matter of trying to reduce accidents and rates rest until it again falls due.

To get all the benefits for safety just mentioned, the employer should keep a close tally of the compensation, medical and hospital payments made by the insurance company to his injured employes, first, to know that the payments are promptly made, secondly, to know that they are fully as liberal as the law requires, and, third, to apportion the payments to the departments where the accidents occur.

Important to Show Department Heads Their Compensation Payments

By apportioning the compensation payments to the department where the accident occurs and as the payments are made, the foreman of the department and his assistants are continually reminded of at least two unpleasant features of an injury, namely, that an accident may occur in only a second of time, but the results to the injured and to the employer may extend over a life time.

The payment of an insurance premium every 6 or 12 months, as the case may be, is likely to fail to impress anyone except the treasurer, when, however, a record of where the money that the premiums represent is kept, and it is known what failure to be safe is costing by departments, and that the burden is accumulative and growing, and when it is also noted what the percentages are over and above compensation and medical payments that the insurance company finds necessary to keep to carry on with, then the facts become impressive, and should be a spur to accident prevention. If such a record is kept and then translated into the resulting added cost per ton of good castings produced, it becomes impressive in a new manner.

The actual out-of-pocket cost of injuries does not complete the story. The reduced production of workmen when partially disabled, the cost of replacing those totally disabled, the cost of stoppage of operations by a large number of workmen when a serious injury occurs. These items should be a further incentive to accident prevention.

Who Is Responsible?

Up to this point nothing has been said about plans and schemes to educate and train the workmen in safe working practices and thinking. Of recent years we have laid too much stress on the part that the workmen has in the prevention of accidents. In the days before the phrase "Safety First" was coined and the staggering job of obtaining it was unloaded on the safety inspector, who's was the job of accident prevention? What did the laws of the land say about it? In plain language, they said that the master must provide a safe place for the servant to work in.

Who else did the law lay a duty on? The agents of the master; and who were they? Any person to whom the master had delegated his authority to oversee and direct his workmen, and whom the workmen were in duty bound to obey; in other words, superintendents and foremen of all grades and degrees. Oversight and direction to obtain production then also included oversight for safety the same as it should now.

We are not saying that all foremen or supervisors have failed

in this respect, but in a large measure the tendency has been to let supervisors step out from under this duty. The concerns that are making the most progress in accident prevention are the ones that are holding all grades of supervisors to a strict accountability. And why not? Do the workmen have anything to say about planning the buildings, designing the equipment, laying out the floors, routing the material through the various departments, etc., etc.? They do not. Management, however, does, and management must be held accountable for accident prevention in all matters relative to the foregoing.

Training of Workmen

Regarding the training of workmen in accident prevention, the problem resolves itself down to the simple propositions of a proper exercise of authority and an enlightened leadership. American workmen, regardless of whether native or foreign born, willingly recognize authority and the need of wholesome discipline, and where these things are combined with leadership, workmen are easy to instruct in all things pertaining to their work, including safety. When the occasional exception, the one dumb or intractable, is found, management has the ways, and means in its control to quickly rid the shop of such a hazard.

Workmen certainly need instruction in safe working practices, but it is far more important that the foremen, and heads of departments, first be thoroughly grounded in all phases of "Safety," not as a separate activity but as "part and parcel" of successful production. When this situation obtains, the training of the workmen speedily follows, and with very few safety meetings or other gatherings for instruction and with a minimum expenditure of time and money.

Properties of Cast Iron of Interest to the Metallurgist, Founder and Engineer

AS PREPARED BY THE SUB-COMMITTEE ON RESEARCH OF THE
COMMITTEE ON GRAY CAST IRON

To the Members of the American Foundrymen's Association:

Your Committee having been charged with the duty of developing tests to determine the usefulness of cast iron, or, as was stated in the resolution, "developing a measuring stick for cast iron," realized that a fundamental necessity of the procedure was to list as completely as could be done the properties of cast iron. We are, therefore presenting the following list, believing it to be reasonably complete, and trust that it may help to develop a sense of appreciation for the differences in different grades of cast iron. The foundryman in using the term "good iron" or "bad iron" may more readily appreciate the fact that he is usually talking of only a few properties, and that what is good iron for him may not be good iron for another, and vice versa.

Respectfully submitted by the Sub-Committee on Research of the Committee on Gray Cast Iron,

JAS. T. MACKENZIE, *Chairman.*

The Properties of Cast Iron of Interest to the Metallurgist, Founder and Engineer

GROUP OUTLINE

I—Causative

- A. Chemical Composition
- B. Physical Constitution

II—Formative

- A. "Coulability"
- B. Volume Change
- C. Cooling Rate
- D. Chemical Reactions
- E. Physical Transformations

III—Effective

- A. Primary or Elementary:
 - 1. Strength
 - 2. Flexibility
 - 3. Hardness
 - 4. Resistance to Corrosion
 - 5. Density
 - 6. Coefficient of Expansion
 - 7. Stability under changes in temperature
 - 8. Conductivity
 - 9. Magnetism
 - 10. Specific Heat
- B. Secondary or Complex:
 - 1. Resilience
 - 2. Machinability
 - 3. Resistance to wear
 - 4. Resistance to abrasion

5. Coefficient of friction
6. Acoustics
7. Ability to be brazed or welded
8. Ability to be enameled
9. Ability to be coated

C. Uniformity.

DETAILS OF GROUPS

I. Causative—Detail of:

A. Chemical Composition:

1. Carbon	}	The general utility group.
2. Silicon		
3. Manganese		
4. Phosphorus	}	The nuisance group, which may be used to advantage.
5. Sulphur		
6. Arsenic		
7. Titanium	}	The "deoxidizer" group, which have alloying properties when present in considerable amounts.
8. Vanadium		
9. Zirconium		
10. Aluminum		
11. Cerium		
12. Boron		
13. Uranium		
14. Nickel	}	The "alloy" group.
15. Chromium		
16. Molybdenum		
17. Tungsten		
18. Copper		
19. Cobalt		
20. Tin	}	The "protective coating" group, and "low melting alloy" group, which have pronounced influence when present as alloying constituents.
21. Antimony		
22. Zinc		
23. Cadmium		
24. Oxygen	}	The gases.
25. Nitrogen		
26. Hydrogen		

27. Solid, liquid or gaseous oxides, which may be in solution, or suspension, either alone or in combination, the most important of which are FeO , MnO , SiO_2 , TiO_2 , Al_2O_3 , V_2O_5 , ZrO_2 , etc.
28. Silicates, ferrates, or other metallic salts of the fluxes, such as calcium, magnesium, etc.
29. Inclusions of molding or facing material.
30. Other elements are possible and not improbable.

B. Physical Constitution:

1. Amount, size, shape and distribution of—
 - a. Graphite
 - b. Phosphides
 - c. Sulphides
 - d. Silicates
 - e. Oxides
 - f. Dirt from mold, core or ladle, or aggregates, solutions, or eutectics of two or more of these.
2. Amount, size, shape and distribution of—
 - a. Ferrite
 - b. Pearlite
 - c. Sorbite
 - d. Troostite
 - e. Martensite
 - f. Austenite
 - g. Ledeburite
 - h. Cementiteor aggregates of two or more of these
3. Amount, size, shape and distribution of solid solutions of iron, manganese, etc., with silicon, sulphur, phosphorous, oxides, gases, etc., and with the carbides

4. Amount, size, shape and distribution of carbides of manganese, chromium, tungsten, titanium, vanadium, etc.
5. Amount, size and shape, and distribution of voids, such as blow holes, shrink cavities and cracks
6. Molecular and atomic structure and arrangement. Ultra-violet and X-ray investigations may resolve some of the apparently elementary constituents cited above
7. Permeability to X-rays, etc.

II. Formative—Details of:

A. Coulability: From "Coulabilité" as defined by Guillet et Portevin; Comptes Rendu, pp. 634, 1926: (German "Giessbarkeit.")

1. Temperature
 - a. Melting
 - b. Of the liquidus
 - c. Of the solidus
2. Fluidity, or its reciprocal, viscosity
3. Specific heat
4. Conductivity
5. Emissivity
6. Heat of fusion
7. Surface tension

B. Volume Change:

1. Liquid contraction
2. Shrinkage in the freezing range
3. Solid contraction

C. Cooling Rate:

1. Thermal gradients

2. Nature of the mold
3. Mass of metal

D. Chemical Reactions:

1. Internal: formation, or decomposition of metallic compounds; and formation, segregation or elimination, according to temperature and cooling rate, of gaseous or solid non-metallics
2. With the walls of the mold or container
3. With the atmosphere
4. With slag or other covering material on the container

E. Physical Transformations:

1. Crystal formation and grain growth
2. Position, magnitude or intensity and duration of the thermal arrests
3. Development of strength to resist or retention of plasticity to yield to the forces of contraction or expansion
4. Development of casting strains

III. Effective—Details of:

A. Primary:

1. Strength in:
 - a. Compression
 - b. Tension
 - c. Bending, expressed preferably as modulus of rupture
 - d. Shear
 - e. Impact
 - f. Torsion
 - g. Fatigue
2. Flexibility, or its reciprocal, Rigidity. Expressed preferably as modulus of elasticity

3. Hardness :
 - a. Penetration
 - b. Rebound
 - c. Scratch
 - d. Pendulum
4. Resistance to corrosion :

This must be determined for each individual corrosive situation, such as soil, atmosphere, high temperature, etc.
5. Density :
 - a. Specific Gravity
 - b. Porosity
6. Coefficient of Expansion
7. Stability under changes of temperature :
 - a. Resistance to growth at high temperatures
 - b. Strength and toughness at high temperatures
8. Conductivity :
 - a. Thermal
 - b. Electrical
9. Magnetism :
 - a. Permeability
 - b. Coercivity
 - c. Retentivity
 - d. Saturation induction
10. Specific Heat

B. Secondary

1. Resilience :
 - a. Capacity for absorbing energy
 - b. Ability to return to shape after deformation
2. Machinability or ease of—
 - a. turning, boring, planing, shaping, etc.

- b. drilling, tapping, reaming, etc.
- c. filing
- d. grinding
- e. polishing

3. Resistance to wear:

This must be determined for each contact material and for each particular condition of lubrication

4. Resistance to abrasion

5. Coefficient of friction with itself and other materials

6. Acoustic properties

7. Ability to be brazed or welded, and value as welding material

8. Ability to be enameled

9. Ability to retain coatings of protective materials

C. *Uniformity, or Homogeneity*

Heterogeneity is often desirable

EXPLANATION

Grouping

A word of explanation may not be amiss. We have considered the causative properties to be, first the Chemical Composition, and second the Physical Constitution. No doubt there is a difference of opinion here, not as to Chemical Composition, but as to Physical Constitution, but there would seem to be no question that the Physical Constitution of pig iron, and certainly that of molten iron, has a considerable, if not a profound, influence on the quality of the casting. For that reason we have included these as Causative.

Under Formative we list all of those properties going to the making of a sound casting, and which affect the condition of the metal in the finished state. They are, of course, largely depend-

ent upon the causative properties and the condition of melting, pouring, etc.

In group III are listed the properties peculiarly of interest to the engineer. These are listed under three sub-groups to emphasize the fact that certain properties are elementary and that others are complex. For instance, machinability is a combination of strength, flexibility, hardness and density, etc. Uniformity is listed as a separate property. It is itself responsible for all of the primary properties listed, and it was only by listing it separately that it could be given adequate importance.

Status of Tests

It is of interest to consider the status of our present methods of testing in the light of this formidable array of properties. Under the chemical composition probably satisfactory methods of analysis are available, until we come to the gases. Here a good deal of work is being done and we hope to have the problem solved in the not distant future. The same is true of the group of Non-Metallic Impurities, such as oxides and silicates.

Under group I—B, probably the most unsatisfactory test in this whole group is the determination of graphite with the subsequent estimation of combined carbon by difference. There is grave reason for doubting the validity of this procedure, and one of our greatest needs is the development of an accurate and reliable direct method for estimating combined carbon in cast iron. The microscopic identification of constituents is rather more troublesome in polishing the specimen correctly than in subsequent identification, as these inclusions are very easily pried out and carried away, leaving nothing to the view except a void.

Under group II, "Coulability" is now being studied by your committee in co-operation with the U. S. Bureau of Standards,

using as a basis the Curry test,* which combines all the factors which go into the making of a sound casting except shrinkage. The investigation recently completed on the temperature measurements of cast iron has shown that for research work the noble metal thermocouple is the only reliable way of getting accurate temperature measurements, but that under works conditions very reliable results may be had with the optical pyrometer if due regard is paid to the critical point in the surface conditions. As might be expected the test for the properties for molten iron are, in general, the poorest in accuracy as the inherent difficulty of working at such temperatures is very great indeed. It is hoped that with the "Coulability" worked out, that is, the composite sum of all of these properties, we may then attack the individual properties, such as fluidity, specific heat, etc., and reduce each one of them to its proper place in the whole scheme.

Under Volume Change there would apparently be no difficulty in obtaining the solid contraction by a refined apparatus, such as Keep used. The liquid contraction, viz.: the contraction of volume from temperatures above the beginning of freezing down to freezing, would be fairly easy, but of not great importance. The main concern of the foundrymen from the standpoint of shrinkage, "piping," etc., is in that contraction between the initiation of freezing and the completion of freezing, and it is this phase that is especially under attack by your Committee at the Bureau of Standards at the present time.

The item, Cooling Rate is not so difficult but rather expensive and troublesome to do on a large scale. However, some studies have been made and are available in the literature.

Of group II—D, Chemical Reactions, is involved with the gas analysis and analysis for oxide inclusions, although the fact

*Curry, C., *Test Bars to Establish the Fluidity Qualities of Cast Iron*, Transactions, A. F. A., vol. 35 (1927), pp. 289-306.

that these are going on can usually be determined, and somewhat of the extent by reference to the analysis of quenched specimens and the final slowly cooled material. In general, we would say that we have no satisfactory test for this group of properties.

Under group II—E, the first two properties are easily tested, but the third and fourth are of prime interest and the Committee knows of no adequate test. Possibly X-Ray analysis may some day solve the difficulty and give us a means of testing casting strains satisfactorily.

Under group III, the Committee feels that very good results are obtained in Compression, Bending, Shear, and Torsion, but that the Tension test is worthy of considerable study, especially with the idea of testing an "as cast tensile bar." The impact test is worthy of study and the fatigue test should be made on a great deal wider scale than has been done. The flexibility usually refers to the deflection in the transverse test and this is not so readily measured as it may seem to be, for with the ordinary Vernier indicating the deflection, unless the operator is watching it at the moment of the break, there is considerable looseness which, in many cases, is added to the true deflection. There is also the problem of the crushing of sand grains on the surface of the bar, etc.

Hardness is readily measured, except that with the small penetrator a very large variation is found in the case of open grain cast iron, as the size of the graphite flakes is too large in comparison with the size of a small penetrator.

There is no test for resistance to corrosion. This can only be determined under the conditions of use to which the casting is put. Laboratory conditions may be arranged to indicate the performance of different cast irons in approximately similar

environments, but this must never be used except as a very general indication, and the small differences should not then be considered.

Under group III—A, specific gravity is easily determined at low temperatures, but porosity calls for at least one known specimen without porosity which in many cases is doubtful. In the case of cylindrical vessels for pressure it can be determined by testing at high pressures, especially with a gas as the testing medium. The other properties of this group are, in general, easily determined.

Under group III—B—Secondary, we have no good test for machinability, resistance to wear and abrasion, and so far the only way to test brazing, welding and enameling, etc., is to make actual tests on these materials. Acoustic properties are readily determined, as is the coefficient of friction. The property of resilience seems to have been much neglected in cast iron, and is most useful in evaluating this material. It would be defined as the area under the bending curve in a test on cast iron. It may be roughly determined by multiplying the breaking load by the deflection, dividing by half, and in most cast iron the curvature will add approximately 20 per cent to the figure so obtained. Ability to return to shape after deformation is easily determined in the ordinary bending test, or in the case of pressure vessels by actual application and release of pressure.

Training Foremen Conference Leaders for Metal Working Plants

BY G. A. MCGARVEY,* WASHINGTON, D. C.

Introduction

My part on this program will be limited to a discussion of the preparation of foreman conference leaders, since other speakers have described very fully the value of foreman meetings and methods of organization.

There seems to be no question in the minds of educators and industrial men but that the conducting of group discussions with foremen is an educational problem, and the leader of such a group must be able to use certain educational methods or procedures which are common to the profession of teaching. It follows, therefore, that those preparing to conduct these meetings should have some training of a definite character in order to be successful in carrying on this type of conference.

Before taking up this part of the subject, I wish to point out the interest which the Federal Board for Vocational Education, in cooperation with the states, has had in developing this phase of trade and industrial education. The need of such assistance to the states and industry was discovered soon after the program of industrial education was established in the states in 1917. In 1919 the first foreman training conference conducted by the Fed-

*In charge of Trade and Industrial Education of Eastern States for the Trade and Industrial Education Service of the Federal Board for Vocational Education. Discussion of this paper begins on page 610.

eral Board was held in the city of Philadelphia, and during the five years following much attention was given to the improvement of the methods of technique used in group discussion meetings.

To illustrate the activities of the Federal Board for Vocational Education during the past ten years, a chart is presented, showing the work of the Federal Board, cooperating with the states, in the development of foreman training from 1919 to 1928. During the first years of this work it was the practice for members of the staff of the Federal Board for Vocational Education to conduct conferences in various plants with groups of foremen. In carrying on these demonstration conferences the purpose was not only that members of the staff could further improve themselves in the methods of conducting conferences, but also to assist state supervisors of industrial education and others to prepare themselves for carrying on this work. During the latter part of this period, from 1924 to 1928, more emphasis was given to the training of conference leaders, and as a result of this program it will be noted that a total of 88 conferences have been conducted in the past ten years in 46 states, in which 1,606 men have participated. Also, as a part of this program, 541 conference leaders have been trained in the states through the cooperation of the Federal Board for Vocational Education. We do not mean to infer that there are not other agencies, both private and public, which have been and are contributing to this important field of education, but for the purpose of this discussion I am limiting my remarks to the publicly aided programs of foreman training which have been started through the assistance of representatives of the federal and state boards of industrial education.

It will be further noted from this chart that the types of industries reached through these conferences vary from trades and occupations found in the field of mining and quarrying to those in the fields of transportation, commerce, and manufacturing. Scarcely any basic industry has not been served by some form of foreman training. Not only have the so-called industrial manufacturing trades been reached, but outside or assembling trades, such as the construction industry, are included in this list.

ACTIVITIES OF THE FEDERAL BOARD FOR VOCATIONAL EDUCATION IN CONNECTION WITH THE DEVELOPMENT OF FOREMAN TRAINING WORK IN THE UNITED STATES 1919-1928



⊙ INDICATES WHERE CONFERENCES HAVE BEEN HELD
⊕ INDICATES CENTERS WHERE CONFERENCE LEADERS HAVE BEEN TRAINED

A TOTAL OF 238 CONFERENCES CONDUCTED IN WHICH 1608 MEN FROM 46 STATES PARTICIPATED
AS A PART OF THE VOCATIONAL PROGRAM 541 CONFERENCE LEADERS HAVE BEEN TRAINED

TYPES OF INDUSTRIES REACHED THROUGH THESE CONFERENCES

- | | | |
|---|---|---|
| <p>1. AGRICULTURE
FERTILIZER MANUFACTURE
MEAT PACKING</p> <p>2. FUEL AND POWER
CITY GASWORKS
CITY DEPARTMENT OF LIGHT AND POWER
GAS AND ELECTRIC WORK
COAL MINES</p> <p>3. METALS
PLUMBING FIXTURES
BRASS WORKS
COPPER SMELTERS
COPPER SMELTING AND REFINING
COPPER MINING
FOUNDRIES</p> <p>4. CONSTRUCTION MATERIALS
LOGGING AND LUMBER MANUFACTURE
PORTLAND CEMENT MANUFACTURE
WOODEN WARE MANUFACTURE</p> <p>5. MACHINERY, RAILWAY EQUIPMENT AND ELECTRICAL APPARATUS
CAR SHOPS (NOT INCLUDED WITH RAILROADS)
IRRIGATION MACHINERY AND PIPING
MACHINE SHOP (EXCAVATING MACHINERY)
MACHINE SHOP (OIL WELL MACHINERY)</p> | <p>MACHINE TOOLS
MACHINE SHOP (PAPER MACHINES)
METAL SPECIALTIES
STEAM BOILERS
WELDING EQUIPMENT
ELECTRICAL MACHINERY
MACHINE SHOP (FLOUR MILL EQUIPMENT)
MACHINE TOOLS (OIL WELL PUMPS)
MACHINE SHOP (TEXTILE MACHINERY)
MACHINE SHOP (AIRPLANE ENGINES)
TRACTOR MANUFACTURE</p> <p>6. TEXTILES AND CLOTHING
COLLAR FACTORY
HOSIERY MILL
TEXTILE FINISHING
TEXTILE MILL (RAYON)
TEXTILE MILLS
TEXTILE MILLS (COTTON)</p> <p>7. LEATHER AND LEATHER PRODUCTS
PAPER MILLS
PRINTING INDUSTRY</p> <p>8. PAPER AND PRINTING
PAPER MILLS
PRINTING INDUSTRY</p> <p>9. RUBBER AND RUBBER PRODUCTS
AUTO TIRES</p> | <p>10. AUTOMOTIVE PRODUCTS
AUTOMOBILE
AUTOMOBILE BODIES
AUTO ELECTRICAL EQUIPMENT
BALL BEARINGS MANUFACTURE
ROLLER BEARINGS
STEERING GEAR</p> <p>11. TRANSPORTATION COMMUNICATION
TELEPHONE COMPANY
ELECTRIC TRACTION COMPANY
RAILROAD SHOP</p> <p>12. CHEMICALS
SUGAR REFINERY
CHEMICAL PLANTS
ELECTROCHEMICAL PLANTS
OIL REFINERIES
PAINT MANUFACTURE</p> <p>13. SPECIAL INDUSTRIES
BRUSH FACTORY
FIREARMS MANUFACTURE
HARDWARE MANUFACTURE
SCIENTIFIC INSTRUMENTS
TYPEWRITER MANUFACTURE
CLEAN FACTORY
LAUNDRIES</p> |
|---|---|---|

CHART 1—FOREMAN TRAINING IN THE UNITED STATES, 1918-1928, IN WHICH MEMBERS OF THE FEDERAL BOARD FOR VOCATIONAL EDUCATION PARTICIPATED.

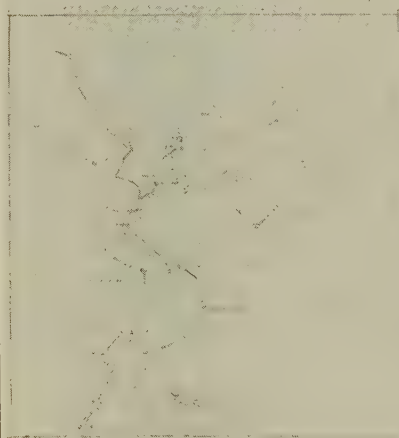
It should not be assumed that this chart covers all the foreman conference work under public supervision in the states. As an illustration of the activities of one or more of the eastern states, we call your attention to the program conducted in the states of New Jersey and New York. These two charts indicate that 430 foremen have participated in conferences conducted in thirteen industries in New Jersey during the past year, and in

IMPROVING FOREMANSHIP

FOREMAN CONFERENCE LEADERS TRAINED FOR INDUSTRIAL PLANTS PHILADELPHIA INDUSTRIAL DISTRICT —

CITY BOARD OF EDUCATION AND STATE BOARD FOR VOCATIONAL EDUCATION

COOPERATING WITH PHILADELPHIA METAL MANUFACTURERS ASSOC.
MAP PHILADELPHIA INDUSTRIAL AREA



LOCATION OF PLANTS

- PLANTS REPRESENTED**
- 1 S.L. ALLEN CO. INC.
 - 2 AMERICAN ENGINEERING CO.
 - 3 CRESSON MORRIS CO.
 - 4 LEEDS AND NORTHRUP CO.
 - 5 LINK BELT CO.
 - 6 MILLER LOCK WORKS
 - 7 NICE BALL BEARING CO.
 - 8 PHILA. STORAGE BATTERY CO.
 - 9 PROCTOR AND SCHWARTZ INC.
 - 10 STOKES SMITH MACHINE CO.
 - 11 BIDDLE GAUMER CO.
 - 12 GENERAL ELECTRIC CO.
 - 13 C.H. HUNT' PEN CO.
 - 14 ROBERTS AND MANDER STOVE CO.
 - 15 SHARPLESS SPECIALTY CO.
 - 16 WESTINGHOUSE ELEC. AND MFG. CO.

A TOTAL OF TWENTY SEVEN CONFERENCE LEADERS FROM SIXTEEN PLANTS TRAINED DURING 1927-28

APPROXIMATELY 400 FOREMEN PROFITED BY THE CONFERENCES LED BY THESE LEADERS

CHART 2—LIST OF PLANTS IN THE PHILADELPHIA INDUSTRIAL DISTRICT SENDING REPRESENTATIVES TO A FOREMAN CONFERENCE LEADERS' TRAINING PROGRAM, 1927-1928.

New York state foremen conferences have been conducted and leaders trained in 23 cities.

Evidence of the Need of Trained Conference Leaders

With the development of any type of educational work, it soon becomes evident that in order to spread the program over any large area, it is necessary to have trained instructors to conduct this work. One individual in a state or large industrial center, devoting all of his time to conducting foreman training conferences in plants and industries, could reach only a certain number during the year. As the demands for this type of service increased, it was found necessary to set up some plan whereby carefully selected individuals from industrial plants could be trained to render this foreman training service in their respective plants; also, that additional leaders would have to be trained to conduct extension programs for the smaller plants, where foremen from several plants might be brought together in some central place. Such programs have been organized by a number of the states, and as a result, rather definite plans of training have been developed and offered through state boards for vocational education and at training institutions. Two charts are presented, which illustrate the types of industries reached and show where the groups are recruited for carrying on these training programs. Chart 2 illustrates the program conducted in the Philadelphia district and Chart 3 illustrates the work carried on in the Wilmington industrial area.

Setting Up Training Programs for Preparing Conference Leaders

Leader training programs have been conducted for representatives from one or more states and for various types of industries. Also, several of the larger cities or industrial districts have conducted leader training programs. To illustrate how such a plan has been carried on, a typical training program for an eastern city will be described. A number of industrial plants and

plant members of the Metal Manufacturers' Association of Philadelphia requested of Pennsylvania State Board for Vocational Education assistance in preparing a group of men representing ten plants located in and about Philadelphia to become foreman conference leaders. Steps leading up to the selection of one or more representatives from these plants took considerable time since it was realized that the training program depended largely on the types of individuals chosen to be trained for this



CHART 3—LIST OF PLANTS REPRESENTED IN FOREMAN LEADER CONFERENCE CONDUCTED JOINTLY BY THE WILMINGTON CHAMBER OF COMMERCE AND THE STATE BOARD FOR VOCATIONAL EDUCATION, 1927-1928.

work. In talking to the management of industrial plants, it was suggested that they select representatives to send to these training conferences who showed evidence of having outstanding characteristics of leadership, that is, foremen who were highly respected by their groups, or executives who were interested in this problem and who could be spared for this special type of plant service. A total of 17 men, including foremen, personnel men, and plant engineers, were selected from ten plants to be trained in this first group. All these men attended throughout the training course, which amounted to a total of 60 hours of time, spread over a period of three months.

Outline of Training Program

The training program for this particular group in Philadelphia was divided up into what might be termed "training stages." The first stage consisted of informing and demonstrating on the

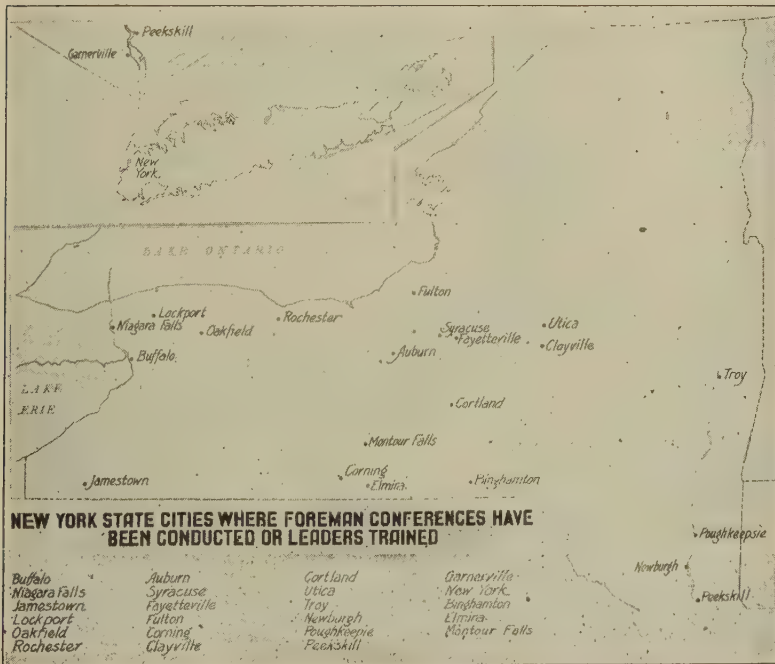


CHART 4—NEW YORK STATE PROGRAM OF FOREMAN TRAINING.

part of the leader in order to show how the group discussion meetings were conducted and pointing out how topics for a series of meetings were derived. The second stage consisted of visits to at least two foreman training conferences conducted in industrial plants. The third stage was taken up with demonstrations on the part of the members of the group of conferences which they had carefully planned and these demonstration conferences were criticized by members of the group. At the end of this period the men were ready to try out group discussions with

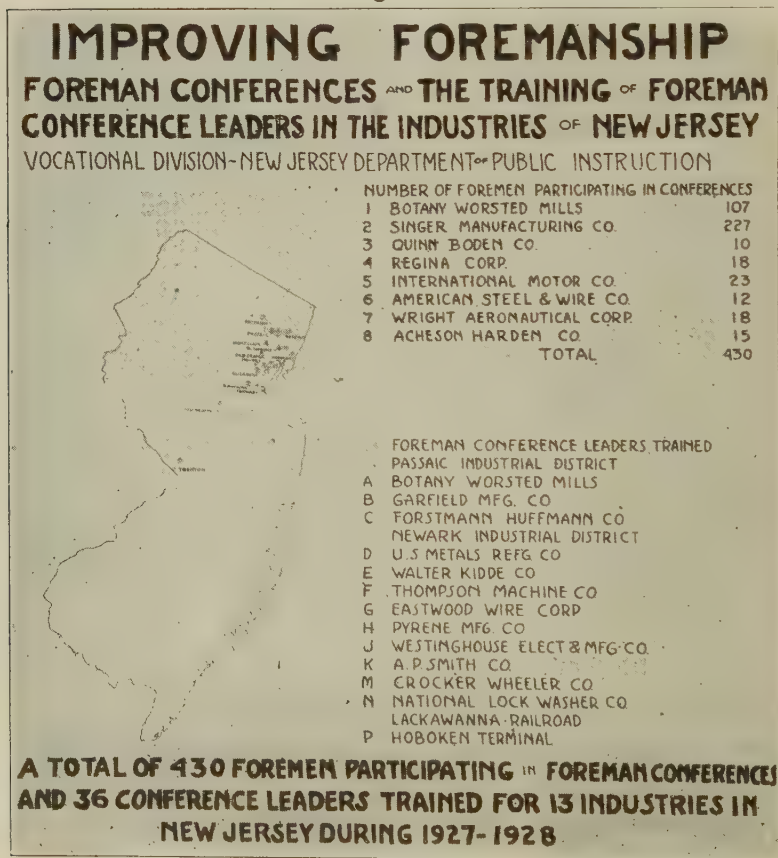


CHART 5—NEW JERSEY STATE PROGRAM OF FOREMAN TRAINING

foremen of their own plants. Further assistance was given to these leaders in outlining a series of meetings and, in some instances, in actually helping them in starting their programs.

After each of the members had conducted one or more series of conferences the group was brought together again for several sessions in order that they could report what progress they had made and what difficulties they had encountered. Next to the observation stage in the training program, this last stage, called "professional improvement," was considered by the men as the most important part of their training experience. As a result of this last session, considerable information was presented which not only indicated where further help was needed, but also pointed out what the individuals should avoid in conducting future series of conferences.

Results Obtained

It is interesting to report that of the 17 men who were trained in this Philadelphia group, 15 have actually conducted a series of conferences which have reached, the past year, several hundred foremen. Other groups of leaders have been trained in Philadelphia, necessitating the assigning by the State Vocational Department of an industrial supervisor to the Philadelphia district to follow up the work that had been started and render further assistance in the training of new groups of conference leaders.

A similar program has been carried out recently in the cities of Wheeling, W. Va., and Wilmington, Del.

Conclusions

The success of foremen's meetings, if they are of the group discussion type, will depend largely on the ability of the leaders properly to direct the discussions. The leader may have considerable natural ability, but in addition to these assets every leader should have some training in order to know how to avoid some of the pitfalls. Also, it may seem that 40 to 60 hours is rather a lengthy period to devote to preparation. Experience, however,

has shown that this amount of time is needed if one is to become thoroughly competent in conducting this type of training.

The training of foreman conference leaders, which has been carried out in many states and larger cities for a number of industries, including foundries, can further be promoted through the interest shown by your Association. Since I am discussing this program entirely from a public educational point of view, I recommend that your Association as a whole, or groups of manufacturers located in industrial centers, request services from your city and state boards of vocational education in further promoting this program of foreman training.

Mold Handling

BY R. J. HEISSERMAN,* PHILADELPHIA, PA.

Earliest Installation Thirty-Eight Years Ago

The successful installation and operation of power mold conveyors in a Pennsylvania foundry more than thirty-eight years ago, was the forerunner of mass production by mechanical means.

This is quite a broad statement, when we consider the benefits now being derived from mass production, but the same general principles of specialized work for each operator, then used, are the backbone of the high production methods of today.

The general design of this early forerunner of the present day mold conveyors consisted of successive carriages about two feet above the floor, each having rollers, and traveling on bulb rails. The carriages were attached to a chain, which formed the propelling medium, and the molding operations were carried out in much the same manner as at present.

While this continuous molding unit was producing castings at one-half cent less per pound, which was quite a saving at that time, other types of conveyors, not quite so successful, were being installed.

Experimental Developments

One of these, similar to the "Old Mill" in amusement parks, consisted of a series of boats floating in a canal. Propellers were

*Link-Belt Company.

Discussion of this paper begins on page 597.

installed at various points around the bottom of the canal to give motion to the water, which in turn moved the boats. The molds were placed on the boats for pouring, cooling, and conveying to the shake-out station. The main idea back of this equipment, or experiment, was smooth handling of the molds, as it was then thought that a mechanical conveyor would break the molds in transit. Many difficulties were experienced in trying to make this carrier work. The main reason for failure was that hot metal dropped into the water, either from the ladle at the pouring station or from run-outs.

Sometime later, the pendulum or trolley type mold conveyor was conceived in the Middle West, and this type is still used with great success in the plant where it originated, as well as in automobile and radiator foundries. This machine consists of long hangers, made of pipes or structural steel, to the bottom of which are attached trays for carrying the mold. Flanged rollers are attached to the hangers at their upper ends, which in turn travel on a flat steel track. A chain is attached adjacent to the rollers to provide motion to the hangers and to keep them properly spaced.

Although an electric motor drive, with the necessary gear reductions and end sprockets, is used on most machines of this type, there are some that are propelled by a wire cable and an air cylinder. The advantage of this machine was, that the rollers, track, and chain, together with all driving machinery, were overhead and safe from falling sand or hot metal. This resulted in smooth travel and minimum wear, but required rather expensive construction.

As time went on, a chain was developed that would stand the wear and tear of sand and hot metal and which, therefore, need not be placed overhead. This did away with the costly overhead steelwork, and also made it possible to locate the motors and driving machinery in pits or at the floor level.

Various designs of this type machine have been made, all of which used the two T rail tracks for supporting the mold tray. The chain on the earlier type conveyors was carried on a separate pair of rails, and was equipped with dogs or attach-

ments for pushing the trays along the tracks. On the later machines, the chain is supported by the trays, as it is attached directly to them, eliminating the extra rails. In most cases this tray slides directly on the rails, although a few have been made in which the trays are fitted with rollers. The smoothest travel is obtained with the sliding trays, as these keep the tracks cleared, while the rollers on the truck trays tend to ride over any obstructions of metal or sand, causing jolts, or will slide, due to shot on the rails, resulting in flat spots on the rollers.

This sliding conveyor is used extensively for the handling of snap flask, and the smaller steel and iron flask molds, although quite a few are handling molds weighing approximately three hundred (300) pounds.

To eliminate a crane or hoist handling from the molding station to the mold conveyor for these heavier molds, the cope and drag are built on a stationary piece of gravity conveyor which is placed at right angles to the power driven mold unit.

The trays of the power mold conveyor are then made up of gravity rolls, which permit rolling the molds onto the conveyor tray from the stationary gravity conveyor as it passes the molding station.

Recent Installations

Very recently there has been developed a power mold conveyor for handling molds of five hundred to six hundred pounds over a great distance with a low power consumption. This conveyor is known as the "anti-friction" type, because of the liberal use of high grade tapered roller bearings. The tracks of this conveyor are attached to the under side of the trays, making it impossible for metal or sand to fall on them, as, besides being inverted, they are always under the tray. The chain is likewise protected in its position under the inside edge of the tray. The inverted tracks ride on large diameter rollers, having pressure lubricating attachments for the roller bearings on which they revolve. The trays completely cover the rollers, as they are overlapping, making a continuous moving platform, and the rollers are thus protected from the sand and iron.

Still another type consists of trays, or pallets, fitted with swivel casters and traveling through a rectangular path. Pro-

pulsion is provided by air cylinders mounted at the corners and giving motion to each horizontal line of trays, the corner turn being accomplished by the nature of the joint between adjacent trays.

Types for Large Production Shops*

The conveyors enumerated thus far are of the continuous power type, that are used in large production foundries, and foundries where it is possible to obtain a continuous flow of metal.

Other types of power driven mold conveyors might be mentioned, but in a great many cases they represent the same general design, with variations to suit the individual case. Special conditions may dictate special forms or applications, suitable only to one or two installations, however, the underlying principle of general design is applicable to all.

Types in Semi-Continuous Foundries

In the semi-continuous pouring foundries, or in foundries where pouring-off is done once a day, we find the following methods of mold handling:

Manual: Where the molder carries out the molds he makes, or has a helper to do this work.

Crane, Jib or Hoist: Operated manually, electrically or by air. Where the crane operator takes the mold from the closing station and places it on the floor, or where the jib and hoist assist the molder or helper in the carry-out. Also where a number of molds are placed on a long frame, or skid, being taken from the molding station by the crane.

Skids and Trucks: Electric or gasoline. Where the molds are loaded on skids by the molder, with a lift truck for moving the skids to the pouring zone, and then to the shake-out station, returning skids and flasks to the molder.

Gravity Roll Conveyor: Where the molder places the molds on the conveyor, which conveys them by gravity to the pouring zone, then to the cooling zone, and thence to the shake-out station. Empty flasks are returned to the molder on a second run of conveyor. In some cases air cylinders have been used to push the molds along the conveyor.

Circular Table: Where the molder places the molds on a circular platform or frame supported by rollers or central pivot frame. The table is then moved by hand or power, the molds being poured, cooled, and shaken out as it moves around. The diameter of the table is governed by the number of molders, the number of molds to be poured at one time, and the amount of cooling time required.

Applications for Various Types of Foundries

The most common application of the power type mold conveyor is in gray and malleable iron foundries, while the cranes, jibs with hoists, skids and trucks, and gravity rolls conveyors, will be found in the steel as well as in the non-ferrous foundries. The circular tables are working to advantage in car wheel, radiator, piston ring and non-ferrous foundries.

Advantages

As it is necessary to have a sand handling system working in conjunction with the mold conveyors to get their full benefit, it is almost impossible to give the exact savings chargeable to the mold conveyors alone. The following items, therefore, cover the combination of sand and mold handling equipments in a continuous pouring gray and malleable iron foundry:

1—Production methods in the foundry:

Continuous operation results in a steady flow of materials and products.

Cleaning room, machine shops and all finishing departments benefit by a systematic, orderly foundry.

Better service on rush orders.

2—Flexible Production for Rush Seasons:

Output doubled by working night shifts. This results in more than double saving as it is accomplished on original investment. Double shift is not possible under old floor methods where the sand preparation is done at night

3—Reduction of Losses Due to Continuous Inspection:

Castings can be inspected ten minutes after molds are made.

Under the old method imperfect castings, due to poor sand, patterns, or metal, are not discovered until a day's production has been poured. This one item alone saves a tidy sum, and should receive serious consideration in working up anticipated savings.

4—Standard Flask Equipment:

It is possible to standardize more on the flask equipment, as a larger volume of sand in some flasks will not affect molding costs. The sand hoppers over molding machines solve this problem.

5—Savings in Flask and Molding Equipment:

A reduction of seventy-five per cent in flask equipment is obtained on a continuous unit over the old floor method. At the same time the production in molds is increased.

In some installations the savings in equipment have covered the cost of the sand handling system.

6—Molders' Efficiency Increased Sixty to Sixty-five Per Cent, due to the following:

Delivery of sand to molding machines from overhead bins, eliminating shoveling.

Conveying molds away from machines eliminates walking and bending to place molds on floor.

Time used for pouring and shake-out is used for molding. Continuous molding all day, with no loss of time waiting for iron, when floor is filled.

Giving the good and speedy molders a chance for high production, by not using up their energy in shoveling and long carry-outs.

Better conditioned sand, free of shot and refuse.

All-round better working conditions, the benefits of which should not be overlooked.

7—Elimination of Night Shifts:

In foundries where the shake-out and conditioning of sand is done by a night gang, it has been possible to omit this

shift entirely, saving from one hundred to one hundred and fifty dollars per night. Where this work is done by the molders, its elimination gives to them that extra time for molding, which should be figured in for the larger production per man.

8—Floor Space Saved:

A complete continuous unit would require less than thirty per cent of the floor space of a floor type foundry and at the same time have double capacity.

9—Operators Become Specialists at Less Cost:

Due to continually performing one operation, the men find short cuts and become experts in their part of the system.

Also, a large percentage of the work formerly done by molders can be done by common laborers.

10—Minimum Mold Breakage:

There is less tendency to break a mold in placing it on a mold conveyor than there is when the molder carries it out and sets it on the floor. This is true, especially if it is necessary to stack snap flask molds, on account of lack of floor space.

11—Systematic Pouring Reduces Cost:

Continuous pouring requires the minimum number of men working through the entire day on the pouring gang, as it does away with the extra labor required when a large volume of metal is poured in a comparatively short time.

Shortest possible carry for the metal, as the pouring zones on the conveyor are located adjacent to the cupolas.

12—Casting Collecting Omitted:

Castings are delivered to one point by the conveying unit, thus eliminating collecting and carrying around the entire foundry area.

13—Saving in New Sand:

New sand requirements are reduced materially, due to proper mixing and preparation.

Minimum burning out of the sand, as the molds are shaken out in shortest safe cooling time.

14—Pace Setter:

Continuous operation tends to speed up production, and set a pace that can be maintained, due to the back-breaking work having been eliminated.

Individual Shop Conditions Govern Installations

Although many of these advantages are also realized in steel and non-ferrous foundries, the conditions surrounding each individual installation, and the methods previously used, determine the saving. Needless to say, the profits realized by steel and non-ferrous foundries fully warrant this type of equipment. The large number of foundries making this installation in recent years proves this point. Numerous records are on file showing a reduction in direct and indirect labor of more than fifty per cent.

Any type of foundry that has increased its volume of business to require new buildings can make a three-fold saving by the introduction of a conveying system in their old buildings. First: they gain the advantages of continuous or semi-continuous production. Second: the sand and mold handling equipment would cost less than half what the new buildings would cost. Third: sufficient room will be saved in the old building to accommodate the extra core and cleaning room requirements needed for the increased production.

The success of these installations is dependent on having the correct layout to meet the individual requirements. Last but not least is needed, a rugged design of the various machines to withstand the wear and tear of sand and iron.

Alloy Cast Steels

BY DAVID ZUEGE,* MILWAUKEE, WIS.

Introduction

During the World War there occurred a very marked increase in the tonnage of steel castings used in the United States. The reasons for this are obvious when one considers the varied uses to which steel castings might be put in a war-time period. The result was an unprecedented demand for greater production which caused many foundries to enlarge their capacities greatly.

Not only was there a demand for greater production, but for increased quality as well. The conditions which the castings were required to meet were analyzed more closely and definite specifications for physical properties were set up. It is true that there had been a definite trend toward standardization prior to this time, beginning about 1902, at which time the American Society for Testing Materials was organized.

Steel casting specifications in 1902 were far below those prescribed today. Typical specifications called for a minimum tensile strength of 60,000 pounds per square inch, and a minimum elongation value of 10 per cent, with no limiting values for yield point or reduction of area.

As the requirements became more severe, the quality of the cast carbon steels became better so that during the war the United

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Discussion of this paper begins on page 630.

States government specifications called for the following minimum values for ordnance steels:

	Yield Point, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Elongation in 2", per cent	Reduction of Area, per cent
Cast Steel No. 1.....	25,000	60,000	16	24
Cast Steel No. 2.....	35,000	75,000	15	20
Cast Steel No. 3.....	45,000	85,000	12	18

Even with these low values, manufacturers at times had difficulty in meeting these requirements, and were required to give the castings long and repeated treatments with little success. These failures, however, were often obscured by the demand for quantity production.

GRAPHICAL RECORD OF ALLOY STEEL
CASTINGS PRODUCTION 1916-1927.
(Data by American Iron & Steel Institute)

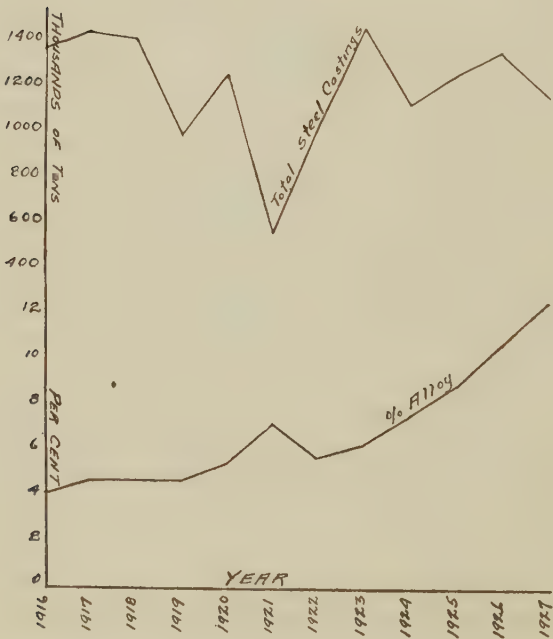


FIG. 1—ALLOY STEEL CASTING PRODUCTION 1916-1927
DATA BY AMERICAN IRON AND STEEL INSTITUTE

With the end of the war, however, came a decrease in the demand. The bookings of steel castings as given out by the Department of Commerce dropped from 105 per cent of the rated capacity in 1918 to 41 per cent in 1919, 68 per cent in 1920, and 26 per cent in 1921. Such a decrease in demand meant the elimination of the weaker producers and the survival of those who could produce castings of excellent quality at a reasonable price. At the same time consumers were making greater demands for quality than ever before. In the machinery field machines were being run faster, in the oil field wells were being dug deeper, and in the power field greater pressures and higher temperatures were being used. These are but typical instances of a general trend which, together with the decrease in demand for steel castings at this time, were responsible for numerous investigations of the adaptability of the various alloying elements to cast steels and which have resulted in a steady increase in the percentage of alloy steel castings made since 1920, as shown by Fig. 1.

Classification of Alloy Steel Castings

Alloy cast steels have been classified by Frank¹ into three groups, as follows:

- I. Steels of high physical properties such as tensile strength and ductility, or resistance to impact, abrasion, fatigue, or distortion.
- II. Steels with extraordinary properties such as resistance to corrosion and magnetic permeability.
- III. Heat resisting steels.

Although all three classes have contributed to the increase in the amount of alloy steel castings made in recent years, the data presented in this paper are confined entirely to steels of the first class with the further restriction that all of the steels investigated are machinable in the normalized or annealed condition.

¹A. F. A. Trans., Vol. 36, p. 120 (1928).

Effects of Alloying Elements on Structure of Steels

The alloying elements most often used for cast steels of this type are chromium, nickel, manganese, vanadium, and molybdenum, or various combinations of the above. Since all of these elements have been used in the various steels to be reported, the following paragraphs will briefly describe their characteristic effects upon the structure of the steel.

Chromium

Chromium is one of the leading alloying elements. Although it is often used in conjunction with another element, a simple chromium steel may be given properties far exceeding those of a plain carbon steel. Chromium has no scavenging power but is used as a true alloying element. Chemically, chromium forms either a chromium carbide, which, in turn, dissolves in the cementite, or a complex carbide of chromium and iron. These carbides are very hard. Therefore, since the hardness which can be procured is dependent upon the carbides formed, the amount of carbon as well as the chromium content is an important limiting value for such steel.

However, chromium increases the hardness not only because of the hardness of these chromium carbides, but because it aids in the retardation of the austenite transformation. Cementite containing chromium not only goes into solution with difficulty, thus raising the critical points on heating, but once in solution does not separate out to form pearlite as readily as ordinary cementite does on cooling. Therefore, in rapid cooling it helps to prevent the transformation of the austenite, thus increasing not only hardness of the surface but depth of hardening as well.

The chromium steels also have a fine structure, which produces higher static strength than the straight carbon steels, with little corresponding loss in ductility.

Nickel

Unlike chromium, nickel dissolves in iron in all proportions and is therefore found dissolved in both the free ferrite and the

pearlitic ferrite of hypo-eutectoid cast steels. The presence of this iron nickel alloy tends to retard the austenite-pearlite transformation in cooling through the critical range and therefore its effect upon the physical properties of the steel is due not only to the added strength imparted to the ferrite, both free and pearlitic, but also to the fact that the iron nickel alloy tends to retain the harder and stronger stages of the austenite-pearlite transformation.

Due to the fact that the nickel produces beneficial properties in the ferrite, it is a very useful element to use in combination with chromium or other elements which impart added properties through their influence upon the cementite.

Manganese

Manganese when added to a steel in an amount in excess of that required either for deoxidation or for the conversion of the sulphur to manganese sulphide must be considered as a true alloying element.

Manganese not only forms a complex iron manganese carbide, but a solid solution of manganese and iron. Manganese has a very favorable effect upon the physical properties of the pearlitic steels, causing high strength accompanied by excellent ductility.

Vanadium

Vanadium is a very powerful deoxidizing agent and it is believed that the beneficial effects obtained through its use are largely due to its elimination of impurities although it also forms complex carbides. In rolled steels it is believed to produce a very fine grain structure. In castings it is used largely in heavy irregularly shaped castings in which it raises the ratio of yield point to tensile strength with no decrease in ductility.

Molybdenum

Swinden² has concluded that in the absence of chromium or excess manganese, molybdenum is diffused throughout the ferrite of the steel, to which it gives greater hardness, but that when chromium or an abnormal manganese content is present, double

²Jnl. Iron & Steel Inst. Carnegie Scholarship Memoirs, Vol. V, 1913.

carbides are also formed, producing greater hardness and strength. He also found that in steels containing 1 to 8 per cent molybdenum—a definite compound of molybdenum iron with iron was formed in cooling through the critical range. When rapidly cooled this compound assumes a “fixed” state and breaks up very slowly on drawing back after the quenching operation. Sargent³ found the same conditions in steels containing 0.25 to 0.50 per cent molybdenum.

The retention of such a compound through a wide range of drawing temperatures explains the fact that after quenching the molybdenum steels retain their high hardness and strength values through a very wide range of draw temperatures. Since molybdenum steels also require a slower cooling rate to produce definite strength and hardness values than most other steels, the strains occurring in these steels after heat treatment should be low.

Reclassification of Steels of Group I

The steels listed under Group I of the classification of cast alloy steels previously referred to may be reclassified into three sub-groups as follows:

- A. Cast alloy steels for general uses where fairly high physical properties are desirable but where no especially severe service conditions are encountered. These steels are usually given no heat treatment other than that given ordinarily in the foundry, although individual heat treatment causes a further improvement of properties.
- B. Cast alloy steels for specific purposes in which very definite physical properties are developed through proper heat treatment of individual castings.
- C. Cast alloy steels for very severe service conditions, thus requiring exceptional physical properties, but where the design of the casting is such as to make liquid quenching impractical.

Since the better physical properties obtainable in groups B and C are secured at an additional cost, either for an increased

³Amer. Soc. for Test. Materials, Vol. XX, 1920.

amount of alloying elements or for the heat treatment of individual castings, the problem confronting both manufacturer and consumer of steel castings is the selection of that steel which will at a minimum total cost most successfully withstand the required service.

In the absence of direct service tests, it is believed that a study of the physical properties obtained on steels of these three sub-groups is the best way of comparing their relative merits. Therefore, values obtained from typical steels of each group will be given.

Representative Alloy Steels of Group A

The two steels which occupy prominent positions in sub-group A are:

1. Vanadium steel
2. 1.20 to 1.60 per cent manganese steel

Table 1
REPRESENTATIVE PHYSICAL PROPERTIES OF .35-.45 C. .18-.25 Va.
CAST STEEL

	Full Annealed	Range of Properties After Various Heat Treatments
Tensile Strength, in pounds.....	85,000	90,000 to 160,000
Yield Point, in pounds.....	50,000	60,000 to 140,000
Elongation in 2", per cent.....	22	20 to 6
Reduction of Area, per cent.....	40	45 to 12
Brinell Hardness No.	180	190 to 450
Scleroscope Hardness No.	25	25 to 55

Table 2
PHYSICAL PROPERTIES OF .27-.37 C. 1.35-1.55 Mn. STEEL

Heat	C.	Mn.	Si.	Yield Point, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Elonga- tion of in 2", %	Reduc- tion of Area, %	Brinell Hard- ness	Charpy Ft. Lbs.
036	0.31	1.32	0.40	62,500	97,850	27	53	212	13.3
036A				54,550	87,650	30	57.3	183	14.2
038	0.33	1.50	0.38	61,200	103,500	23.5	49.5	212	11.2
038A				51,200	89,100	28	58.3	183	13.3
049	0.32	1.42	0.40	58,300	92,000	26	45.4	192	13.9
049A				55,050	83,250	31.5	55.7	166	16.4
098	0.32	1.54	0.48	64,250	110,200	22.5	47.8	228	15.1
098A				59,950	95,850	24	54.4	202	14.5
155	0.37	1.44	0.28	61,450	98,800	20	32.8	202	4.1
155A				58,200	93,600	24.5	49.7	170	4.5
167	0.33	1.46	0.31	61,350	95,800	25.5	49.3	192	13.3
167A				51,950	86,350	32.5	57.8	183	18.3

Bars having no suffix were held at 1650° F. in shop annealing furnace for three hours, then cooled in air.

Bars having the suffix A were drawn for three hours at 1250° F. after receiving individual air quench from 1650° F.

Size of coupon, 1" x 1" x 6".

Vanadium Steels

The vanadium steels have in the past been used to a considerable extent in castings where an exceptionally clean metal was desired or where castings of intricate design were required, since vanadium does not confer marked air hardening properties. It was believed that vanadium imparted to steels the ability to resist repeated stress to a marked degree, but some recent investigators believe that its importance in this respect has been exaggerated.⁴ Vanadium cast steels having a carbon content of 0.35 to 0.45 per cent and 0.18 to 0.25 per cent vanadium will develop the average physical properties given in Table 1.

1.20 to 1.60 Per Cent Manganese Steel

The use of this steel for castings requiring a combination of high strength and high ductility has increased greatly in recent years. Hall⁵ has done a considerable amount of work in the development of this type of steel and has at various times published representative physical properties of the material. The values given in Table 2 are taken from tests on routine heats and are in substantial agreement with those of Hall. These data show that the effect of the draw at approximately 1250 degrees Fahr. is to increase the ductility and impact values but to decrease the yield point and tensile strength. The physical properties both with and without the draw are very satisfactory and the choice of the treatment is dependent upon the use to which the castings are to be put.

The superiority of this type of steel over a typical 0.40 to 0.50 per cent carbon steel is shown in an interesting manner by some tests on hollow steel cylinders shown in Fig. 2, the results of which are tabulated in Table 3. These tests were made on cylinders machined from solid cast steel blocks to the size shown in Table 3, which were then tested to destruction in a testing machine.

C and D in Fig. 2 show respectively a 0.40 to 0.50 per cent carbon and a manganese carbon cylinder originally 1.5 inches in height compressed to a height of 1.06 inches, at which height cracks occurred in the 0.40 to 0.50 per cent carbon cylinder.

⁴Gillett and Mack—*Molybdenum, Cerium, and Related Alloy Steels*, p. 37.

⁵Trans. A. F. A.—*Manganese in Cast Steels*, Vol. XXXIV, p. 1152, 1926.

Table 3
COMPARATIVE TESTS OF .40-.50 C. AND 1.25-1.60 Mn. CAST STEEL

Cylinder Number	Kind of Steel	Size of Cylinder	Actual Load, lbs. per sq. in.		Stress in lbs. per sq. in.		Height of cylinder when first crack occurred:	
			Yield Point	Ultimate	Yield Point	Ultimate	Actual Inches	Per Cent of Original
A*	.40-.50 C.	1.5" x 1.312" ID x 1.5" OD	18,760	38,650	54,100	92,900	1.06	70.5
C*	.40-.50 C.	1.5" x 1.312" ID x 1.5" OD	19,000	38,640	45,700	92,900	1.03	69.7
H*	.40-.50 C.	3" x 1.312" ID x 1.5" OD	19,390	38,230	46,500	92,000	2.37	79.7
B†	Mn. C.	1.5" x 1.312" ID x 1.5" OD	28,880	46,550	69,500	112,000	0.37	24.6
D†	Mn. C.	1.5" x 1.312" ID x 1.5" OD	27,900	45,330	67,550	109,000	0.42	28
E†	Mn. C.	3" x 1.312" ID x 1.5" OD	27,130	44,510	65,250	107,000	1.5	50

*Analysis: C, 0.43; Mn, 0.72; Si, 0.45. Heat treatment: Held three hours at 1650° F. Cooled in furnace.

†Analysis: C, 0.31; Mn, 1.56; Si, 0.41. Heat treatment: Held three hours at 1650° F. Cooled in air.

Table 4
PHYSICAL PROPERTIES OF 1.25-1.60 MANGANESE CARBON STEEL, OIL QUENCHED AND DRAWN

Heat Treatment	Yield Point, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Elongation in 2", per cent	Reduction of Area, per cent	Brinell Hardness	Scleroscope Hardness	Charpy Impact, Ft. Lbs.	Endurance Limits, lbs. per sq. in.
O	63,500	101,200	23	47	228	35	8.6	41,000
	60,200	101,000	22	43.6			8	
A	100,950	144,300	8	22	321	50	2.8	57,000
	Bar broke at shoulder.						2.8	
B	95,050	132,350	11.5	33.8	286	45	7.8	51,000
	89,650	130,850	15	34.7			8	
C	72,000	100,400	22	51.7	228	43	14.4	46,000
	73,900	102,800	21	49.7			14.4	
D	57,400	100,450	24.5	50.6	187	35	23	42,000
	58,900	96,950	23	54			24.2	

Heat Treatments

O normalized two hours at 1650° F.
 A normalized two hours at 1650° F. Held two hours at 1550° F. Quenched in oil; drawn at 600° F.
 B normalized two hours at 1650° F. Held two hours at 1350° F. Quenched in oil; drawn at 900° F.
 C normalized two hours at 1650° F. Held two hours at 1350° F. Quenched in oil; drawn at 1200° F.
 D normalized two hours at 1650° F. Held two hours at 1350° F. Quenched in oil; drawn at 1350° F.

Size of coupon, 1" x 1" x 6".

A shows cylinder C compressed to a height of 0.75 inch, at which complete rupture occurred.

B shows the manganese carbon cylinder compressed to a height of 0.5 inch, at which height the first cracks occurred.

H and E in Fig. 2 show the relative deformation obtained on the 3 inch cylinders of both 0.40 to 0.50 per cent carbon and manganese carbon before cracks appeared. The manganese carbon cylinders had not only better ductility as shown by the photographs but greater strength as well.

Although by far the greater proportion of the manganese carbon steel is used in the normalized full anneal, or normalized and drawn condition because of the excellent results secured by these treatments, a considerable increase in the various physical properties may be secured by resorting to a liquid quench.

Table 4 gives the results obtained by drawing 1" by 1" by 6" test bar coupons of a typical manganese carbon heat at various temperatures after an oil quench from 1550 degrees Fahr. These data show that the liquid quench followed by a low draw produces a marked increase in strength, hardness, and endurance limit over the normalized steel, and a decrease in ductility and resistance to shock. As the draw temperature is increased, a corresponding increase occurs in ductility and shock resistance, with a decrease in strength and hardness and endurance limit.

Figs. 3 and 4 show the results of the fatigue tests which were made, using the R. R. Moore Fatigue Testing Machine.

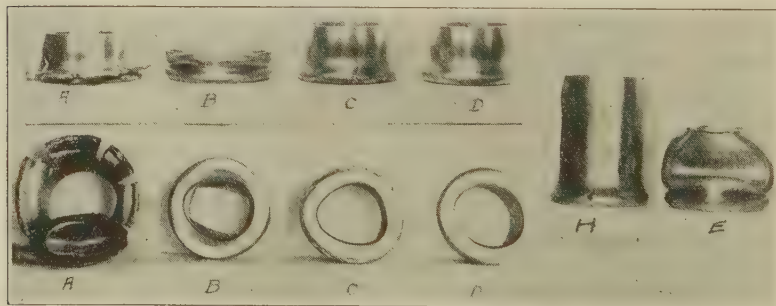


FIG. 2—COMPARATIVE TESTS OF CYLINDERS MADE OF 0.40 TO 0.50 C. AND 1.25 TO 1.60 MN. CAST STEELS

S-N DIAGRAM—SHOWING ENDURANCE LIMIT OF CAST STEEL

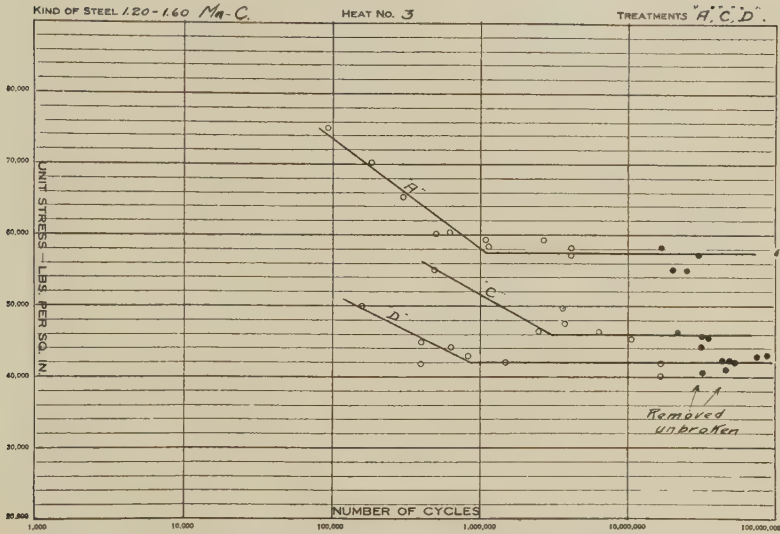


FIG. 3—ENDURANCE LIMIT CURVES FOR STEEL OF TABLE 4, HEAT TREATMENTS A, C AND D

S-N DIAGRAM—SHOWING ENDURANCE LIMIT OF CAST STEEL

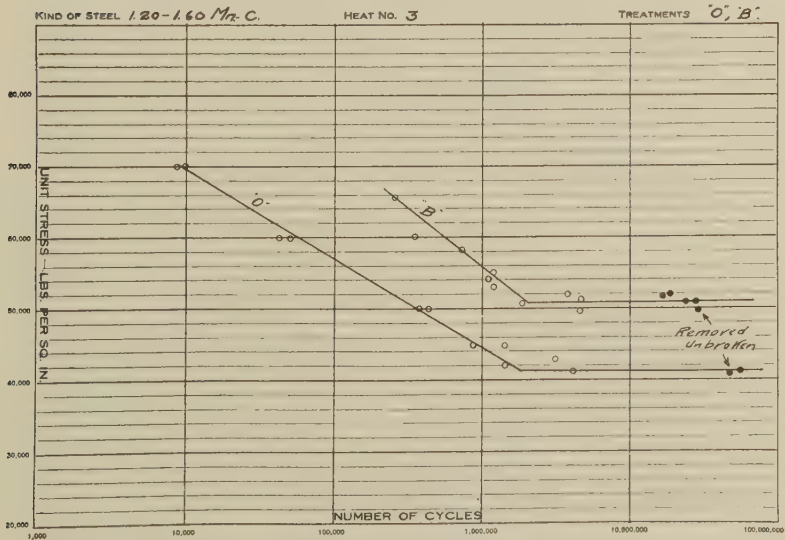


FIG. 4—ENDURANCE LIMIT CURVES FOR STEEL OF TABLE 4, HEAT TREATMENTS O AND B

The data given in the previous tables, while not voluminous, are sufficient to demonstrate what can be expected from cast steel of this type and in conjunction with results of other investigators show its superiority over plain carbon steels in the normalized, annealed and oil quenched condition. However, when a liquid quench is used the steels classified in this paper under sub-group B give somewhat better results at the higher hardness values.

Representative Alloy Steels of Group B

0.35 to 0.45% C., 0.75 to 1.00% Cr. Steel

Chromium, especially when in combination with nickel, imparts very marked hardening properties to the steel. Therefore, chromium is a very satisfactory alloying element and most of the alloy castings which are being individually heat treated today contain an appreciable amount of chromium either alone or in

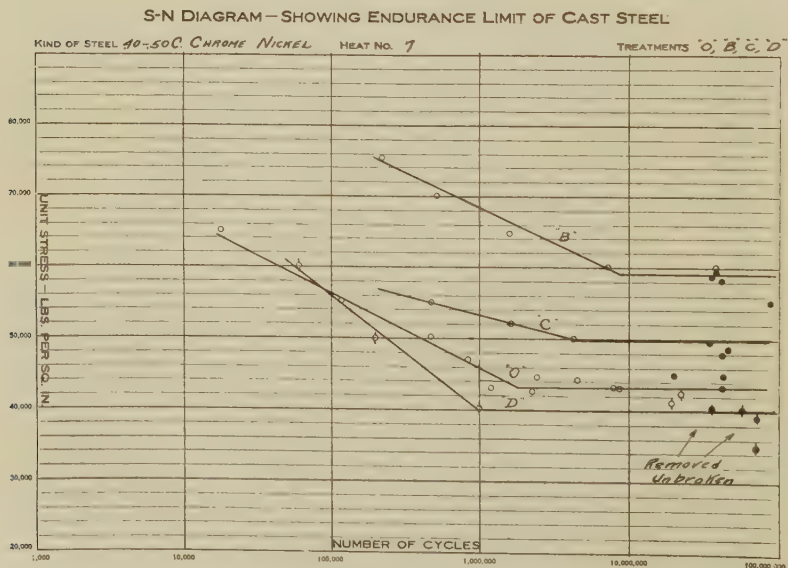


FIG. 5—ENDURANCE LIMIT CURVES FOR STEEL OF TABLE 9, HEAT TREATMENTS O, B, C AND D

combination with other alloying elements. This is due not only to its remarkable hardening and strengthening power but to the fact that its cost is relatively low. Cast steels having a carbon range of 0.35 to 0.45 per cent and a chromium range of 0.75 to 1.00 per cent have for a number of years been giving excellent service after suitable heat treatment for castings where abrasion resistance is required as in tractor shoes and wearing plates.

In the normalized and drawn condition it develops strength values about equal to the 1.20 to 1.60 per cent manganese carbon steel but is not as ductile as a comparison of Tables 2 and 5 will show. Table 5 shows the values obtained on eight average heats taken from the laboratory record.

Table 6 shows the effect of various heat treatments upon a typical heat of chrome steel.

Table 5

PHYSICAL PROPERTIES OF NORMALIZED AND DRAWN .35-.45 C.
.75-1.00 CHROME STEEL

Heat No.	C.	Mn.	Si.	Cr.	Yield Point, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Elongation in 2", %	Reduction of Area, %	Brinell Hardness
1	0.43	0.76	0.35	0.78	58,400	99,150	15	23.5	217
2	0.38	0.74	0.50	0.81	54,650	97,000	19	30	217
3	0.35	0.67	0.37	0.77	56,000	97,050	17.5	26	207
4	0.42	0.74	0.40	0.94	51,000	91,400	18	25.5	212
5	0.38	0.79	0.36	0.90	57,250	95,050	15	18	223
6	0.34	0.71	0.40	0.77	51,300	90,000	20	36.5	223
7	0.38	0.82	0.40	0.80	53,600	93,400	18.5	26	217
8	0.45	0.82	0.50	0.68	54,500	95,750	18	26	201

Heat treatment: Held at 1650° F. for three hours in shop electric furnace; cooled in air on annealing car; drawn at 1250° F. Size of coupons, 1" x 1" x 6".

Table 6

EFFECT OF VARIOUS HEAT TREATMENTS UPON CHROME STEEL

Bar No.	Quench Temp., ° F.	Quench Medium	Draw Temp., ° F.	Yield Point, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Elongation in 2", %	Reduction of Area, %	Brinell Hardness
1	1550	Air	None	74,400	120,800	8.5	12.6	241
2	1550	Air	700	77,850	122,600	13.5	20	228
3	1550	Air	1200	67,150	110,850	17	25	217
5	1550	Oil	700	156,350	193,600	3.5	3.5	418
9	1550	Oil	900	143,250	163,650	8.5	14.1	340
12	1550	Oil	1200	90,200	120,450	16	35.7	241
13	1550	Oil	1350	73,300	100,000	19.5	40.4	207

Analysis: C., 0.39; Mn., 0.84; Si., 0.48; Cr., 0.79. All coupons were given a preliminary normalizing treatment at 1650° F. Size of coupons, 3/4" dia. x 6".

0.40 to 0.50% C., 0.75 to 1.00% Cr., 1.00 to 1.50% Ni. Steel

The addition of a second alloying element to a chrome steel affects the steel not only through the beneficial characteristics of the added alloying element itself but also because it intensifies the hardening effects of the chromium. Therefore in the rolled steels a large number of steel containing chromium in combination with other alloying elements are manufactured. By far the most important and widely used cast chromium steels are those containing also various percentages of nickel.

Table 7 is a record of the physical properties of eight routine chrome nickel heats of the analyses shown, and Table 8 shows the effect of heat treatment upon the tensile properties of a typical heat of chrome nickel cast steel. Table 9 gives the effect of heat treatment on the physical properties, including endurance

Table 7

PHYSICAL PROPERTIES OF NORMALIZED AND DRAWN .40-.50 C., .75-1.00 Cr., 1.00-1.50% Ni. STEEL

Heat No.	C.	Mn.	Si.	Cr.	Ni.	Yield Point, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Elongation in 2", %	Reduction of Area, %	Brinell Hardness
1	0.46	0.80	0.48	0.95	1.29	62,000	101,000	20	35.5	235
2	0.37	0.76	0.39	0.98	1.33	66,450	104,250	22.5	42	222
3	0.38	0.69	0.49	0.94	1.22	66,300	103,200	18	34	217
4	0.42	0.77	0.41	0.89	1.28	68,200	100,000	17.5	36	217
5	0.41	0.78	0.36	0.85	1.27	66,450	99,800	14	16.5	222
6	0.42	0.77	0.46	0.85	1.28	70,000	107,350	21	34.5	222
7	0.45	0.62	0.44	0.85	1.27	64,150	106,400	20.5	37.5	228
8	0.40	0.77	0.56	0.85	1.50	70,400	110,500	20.5	33.5	235

Heat treatment: Held at 1650° F. for three hours in shop annealing furnace; cooled in air on annealing car; drawn at 1250° F. Size of coupons, 1" x 1" x 6".

Table 8

EFFECT OF HEAT TREATMENT ON CHROME NICKEL CAST STEEL

Bar No.	Quench Temp., ° F.	Quench Medium	Draw Temp., ° F.	Yield Point, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Elongation in 2", %	Reduction of Area, %	Brinell Hardness
1	1550	Air	...	149,950	174,050	2.5	4.3	364
2	1550	Air	700	119,200	157,900	9	22.3	321
3	1550	Air	1200	88,250	117,950	18	43	241
4	1550	Oil	700	173,300	202,350	6	11.1	487
5	1550	Oil	900	149,000	182,950	8.5	18.4	387
6	1550	Oil	1200	105,680	125,250	17.5	38.8	269
7	1550	Oil	1350	79,800	108,050	24	49.8	217

Analysis: C., 0.47; Mn., 0.74; Si., 0.45; Cr., 0.99; Ni., 1.44. All coupons were given a preliminary normalizing treatment at 1650° F. Size of coupon, 3/4" dia. x 6".

limit of a second heat of chrome nickel steel having slightly lower chrome and nickel content than the heat recorded in Table 8. Fig. 5 shows the endurance limit curves.

A comparison of the results in Tables 5 and 6 with those in Tables 7 and 8 shows the superiority of the chrome nickel steel over the chrome steel under every type of heat treatment used. Since the analyses given are typical of those used in many foundries making chrome nickel castings, this analysis may be used as a typical representative of the steels of sub-group B for comparison with the properties of sub-group A.

Comparison of Chrome Nickel and Manganese Carbon Steels

Referring now to Tables 2, 4, 7, and 9, it may be noted that the normalized and drawn chrome nickel steel has slightly higher values for yield point and tensile strength than the normalized manganese carbon steel, but also has considerably less ductility. Therefore, with the usual foundry heat treatments, the difference between these steels is not as great as when a more drastic quench is resorted to. The more rapid quenching

Table 9

EFFECT OF HEAT TREATMENT ON CHROME NICKEL CAST STEEL									
Heat Treatment	Yield Point, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Elongation in 2", %	Reduction in Area, %	Brinell Hardness	Sclerometer Hardness	Charpy Impact Ft. Lbs.	Endurance Limit lbs. per sq. in.	
O	65,800 60,380	115,750 114,000	18.5 19.5	28.9 30.5	217 217	35-37	8.6 8.3	43,000	
A	Bars not machinable.				512				
B	170,350 174,000	184,250 186,100	8.5 7.5	17 13.4	364 364	52-58	3.1 3.1	59,000	
C	88,450 89,350	107,800 108,000	24.5 27.5	48.6 47.8	255 269	45-50	10.9 9.8	50,000	
D	79,100 82,650	103,300 103,800	27 26.5	49.2 50	197 197	28-35	18.3 14.8	40,000	

Heat Treatments

- O normalized at 1650° F. (two hours' soak); drawn three hours at 1250° F.
 A normalized at 1650° F. (two hours' soak). Held two hours at 1550° F.; quenched in oil; drawn at 600° F.
 B normalized at 1650° F. (two hours' soak). Held two hours at 1550° F.; quenched in oil; drawn at 900° F.
 C normalized at 1650° F. (two hours' soak). Held two hours at 1550° F.; quenched in oil; drawn at 1200° F.
 D normalized at 1650° F. (two hours' soak). Held two hours at 1550° F.; quenched in oil; drawn at 1350° F.

Analysis: C., 0.48; Mn., 0.70; Si., 0.45; Cr., 0.80; Ni., 1.24. Size of coupon, 1" x 1" x 6".

greatly emphasizes the hardening and strengthening effects of the chromium and nickel so that at the higher hardness values the chrome nickel steel is a better steel. Note that for Charpy impact values of 2.8 and 3.1 foot pounds respectively, the manganese carbon and chrome nickel steels show 144,300 and 184,250 pounds per square inch tensile strength. Not only does the chrome nickel steel have greater ductility than the manganese carbon steel through the top portion of the Brinell range to which it is possible to harden the manganese carbon steel, but it is capable of being hardened to a much higher Brinell value.

Thus, the manganese carbon steel is usually used in those cases where moderately high strength values accompanied by excellent ductility are required. The chrome nickel steel does not show markedly better properties than the less costly manganese carbon steel when both are given the usual type of foundry heat treatment.

On the other hand, the distinct advantage of the chrome nickel steel is that its properties may be improved by proper heat treatment of individual castings to a far greater degree than is possible with the manganese carbon steel.

In the quenching operation, however, strains are set up by the very rapid cooling action which may crack the castings before the strain has been relieved by the drawing operation. Therefore, in any castings where quenching is resorted to for development of maximum physical properties the design should be such as to minimize strains. Abrupt changes in section and sharp corners should be avoided in such castings.

Representative Alloy Steels of Group C

Whenever exceptional properties are required in castings of intricate design, a steel having air hardening properties is desirable. Because of the strains set up by the exceptionally rapid

cooling of castings of complicated design or abrupt change in section, it is impossible at times to liquid quench castings of this type. The element molybdenum imparts marked air hardening properties, especially when in combination with another hardening element, and is considered as the characteristic constituent of air hardening cast steels. Its use in recent years has increased rapidly. Molybdenum alloy cast steels are being made in a variety of analyses. A popular one is 0.40 to 0.60 per cent carbon and 0.25 to 0.35 per cent molybdenum in combination with chromium.

Although the use of molybdenum in cast steels is increasing, very few data have been published giving physical properties which may be obtained from these steels. The writer has been investigating the properties of various types of molybdenum steels. Although endurance limit tests have not been completed, the results obtained for the other properties show that certain combinations containing molybdenum will develop exceptional values.

As a special representative of this group a chrome nickel molybdenum manganese combination has been selected and Table 10 gives the properties obtained on each of four heats of this material under 5 different heat treatments. Note that the carbon content has a decided influence on the air hardening properties as shown by the Brinell values in Table 10, heat treatment A.

With a carbon content of 0.34 to 0.42 per cent an air quench followed by a 700 degree Fahr. draw produced tensile strength values over 200,000 pounds per square inch, yield point over 160,000 pounds per square inch, and minimum elongation and reduction of area values of 10 per cent and 28.9 per cent respectively. Increasing the draw to 1250 degrees gave the following minimum for the same carbon range: Yield point, 90,000 pounds per square inch; tensile strength, 119,000 pounds per

Table 10

PHYSICAL PROPERTIES OF Mn., Cr., Ni., Mo. STEEL

Heat No.	Carbon, %	Brinell	Yield Point, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Elongation in 2", %	Reduction of Area, %	Charpy Impact Ft. Lbs.
A—Held at 1650° F. two hours; air quenched; drawn at 700° F.							
3	0.28	364	145,850	174,350	11.5	30.9	2.6
		364	151,500	175,950	11.5	34.7	2.6
9	0.28	340	112,300	159,250	13	41	2.3
		340	114,200	161,050	13.5	40	10.3
6	0.34	477	174,750	238,000	10	30.5	3.1
		477	176,000	242,000	8.5	28.9	3.1
12	0.42	430	160,300	206,200	10	31.5	3.1
		430	173,150	204,350	10	31.5	2.8
B—Held at 1650° F. two hours; air quenched; drawn at 1000° F.							
3	0.28	364	112,300	164,050	13.5	32.8	8.1
		364	125,000	163,350	13.5	29.5	5.8
9	0.28	340	116,700	153,300	15.5	35.4	8.1
		340	116,000	153,750	15.5	36.8	7.9
6	0.34	387	145,750	177,000	13.5	35	9.2
		387	139,000	174,650	13.5	38.1	9.6
12	0.42	402	148,750	179,150	15.5	37	7.3
		402	143,300	176,000	13.5	35.4	7.3
C—Held at 1650° F. two hours; air quenched; drawn at 1250° F.							
3	0.28	255	90,400	119,350	22.5	53.3	23.3
		255	86,750	118,100	23	51.9	22.2
9	0.28	241	81,750	111,750	22	51.5	19
		241	80,600	111,400	23	51.7	17.7
6	0.34	269	90,900	123,450	23	51.7	20.1
		269	93,250	123,650	22.5	50.6	21.7
12	0.42	269	91,100	119,200	19.5	40.1	23.8
		269	90,550	119,700	19.5	45.4	23.2
D—Held at 1650° F. two hours, air quenched; held at 1550° F. two hours, oil quenched; drawn at 1000° F.							
3	0.28	402	167,000	181,450	13	36.6	11.4
		402	176,700	182,700	12.5	32.1	10.3
9	0.28	418	171,750	181,150	15.5	44	11.4
		418	171,850	183,350	15.5	45.2	12.1
6	0.34	418	173,750	197,100	11	25.4	8.1
		418	169,500	194,600	11	22.7	7.6
12	0.42	418	171,000	193,000	11	27.2	7.1
		418	168,600	192,400	10.5	23.4	8.1
E—Held at 1650° F. two hours, air quenched; held at 1550° F. two hours, oil quenched; drawn at 1250° F.							
3	0.28	255	93,900	120,200	22.5	43.4	22.5
		255	91,000	117,700	21.5	48.1	19
9	0.28	255	81,100	114,050	25	53.8	25.8
		255	75,850	114,300	24	53.3	24.5
6	0.34	269	92,350	126,500	21.5	42.8	23.2
		269	103,500	125,000	17.5	48.6	19
12	0.42	269	93,000	121,950	21.5	39.1	20.5
		269	94,500	127,650	17	33.7	21.7

Size of coupon, 1" x 1" x 6".

Table 11

BRINELL HARDNESS VALUES OF Mn., Cr., Ni., Mo. STEEL

Heat No.	Quench in air at 1650° F.				Air quench at 1650° F.; then oil quench at 1550° F.		
	No Draw (Av. of 6)	Draw at 700° F. (Av. of 2)	Draw at 1000° F. (Av. of 2)	Draw at 1250° F. (Av. of 2)	No Draw (Av. of 4)	Draw at 1000° F. (Av. of 2)	Draw at 1250° F. (Av. of 2)
3	387	364	364	255	504	402	262
6	514	477	387	269	555	418	269
9	331	340	340	241	512	418	255
12	461	430	430	269	555	418	269

Size of coupon, 1" x 1" x 6".

square inch; elongation, 19.5 per cent; reduction of area, 40.1 per cent. The impact values are also very high, 20.1 being the minimum.

THE ANALYSES OF THE STEELS OF TABLE 10 WERE AS FOLLOWS:

	No. 3	No. 6	No. 9	No. 12
Carbon	.28	.34	.28	.42
Manganese	1.56	1.58	1.58	1.48
Silicon	.41	.40	.44	.34
Chromium	.68	.71	.63	.60
Nickel	1.18	1.22	1.18	1.26
Molybdenum	.36	.32	.37	.39

Table 11, which tabulates hardness data, shows that with drawing temperatures as high as 1000 degrees Fahr. considerable hardness is maintained, even though only an air quench is given. This enables strains to be removed from intricate castings without sacrificing hardness to too great an extent.

Comparisons of Steels in Groups A, B, and C

Physical Properties

In comparing the results of the typical heats for the three groups, all of which heats have been made in the acid electric furnace and which have received degasifying additions in sufficient quantity to prevent objectionable porosity in green sand molds, Tables 4, 9, and 10 show the following:

A. When normalized at 1650 degrees Fahr. and drawn at 1275 degrees Fahr., the molybdenum steel has markedly better all around properties than either the manganese carbon or chrome nickel steels. Its superiority is greatest in yield point and Charpy impact values.



FIG. 6—MICROGRAPHS—A, 1.20 TO 1.60 MANGANESE CARBON STEEL—B, CHROME NICKEL STEEL—C, MANGANESE, CHROME, NICKEL, MOLYBDENUM STEEL—MAGNIFICATION 100X—ETCHED IN 2% HNO₃

B. The molybdenum containing steel has exceptional air hardening properties. A simple air quench and draw treatment of the latter steel develops properties equal to and in many instances superior to those obtained by a liquid quench on the other types.

C. When liquid quenching is employed, to obtain high hardness values the molybdenum steel is superior to the chrome nickel, which in turn is better than the manganese carbon steel.

It has greater hardening possibilities, and for any definite fairly high hardness value has greater toughness and ductility than the chrome nickel.

Microstructure

Fig. 6 shows specimens taken from bars whose values are shown in Tables 4, 9, and 10. Each bar has been normalized at 1650 degrees Fahr. and then drawn at 1250 to 1275 degrees Fahr. In the manganese carbon specimen the ferrite has separated to the grain boundaries; in the nickel chromium it has started to segregate into irregular areas, and in the steel containing molybdenum very little ferrite segregation has occurred. This is in accordance with the hardness and yield point values which the various steels showed.

Although micrographs of the oil quenched specimens show far greater structural refinement, in this paper only those micrographs are shown which show the typical structure obtained under the treatment most often used commercially in the foundry today for alloy steels, i. e., normalized and drawn.

Cost

The manufacturing cost of the steels of the three groups increases progressively from A through C. This is due not only to the cost of the additional alloying elements, but also to the fact that as the hardening tendencies increase, greater care must be used in molding as well as cleaning room practices. The steels of groups B and C are usually tender in the cast condition, are susceptible to cracks and breakage, and because of their

hardening properties, are difficult to grind and chip in the cleaning room. They often require a preliminary heat treatment before sending to the cleaning room. Hence, the proportional cost increase for the high alloy steels is greater than the actual increase in cost of alloys used.

Conclusions

Data have been presented by the author to supplement information contributed by other investigators relating to alloy steels adapted to foundry use. The interest the subject holds for many producers and consumers makes advisable the free interchange and the broad publication of reliable information on the subject, for the benefit of all concerned. The author believes that those who make common or carbon steel castings and those who make special or alloy steel castings will best promote the profitable and otherwise satisfactory distribution of their products only as these producers make generally available, accurate information showing typical properties, and only as these manufacturers, after discriminating consideration, recommend conscientiously whatever grade of steel, common or alloy, may appear best adapted to the job in hand.

Selection of the steel to be employed involves economics, which is outside the scope of this paper, except as it may now be touched upon in appropriate closure. We have indicated that the manufacturing costs of the steels herein described increase in the same relative order as do their physical properties that are regarded as desirable for many severe service conditions, where toughness alone or in conjunction with one or more additional characteristics is highly important. Heat treatment costs must be considered as well as metal, molding, and other items of expense incurred prior to the final forming of the casting. Machining costs must not be disregarded, although it should be appreciated by consumers that generally speaking, as the toughness of a metal

is increased, the latter necessarily offers more resistance to many kinds of punishment, to one of which the material is unquestionably subjected when it is machined. Maximum toughness and minimum mechanical effort in machining appear to be incompatible. Modern machine tools have been wisely designed so as to apply great machining force with relatively small noticeable effect on direct finishing expense. The final cost of the casting, influenced greatly by its durability, is the paramount economic consideration.

It seems worth while, in speaking of durability, to mention the all-important fact that in a sense peculiar to the foundry, the chemical composition of the material of which the article is made is by no means conclusive evidence of the serviceability of the manufactured piece. The extent to which this applies becomes greater as we leave the field of common or carbon steels, and extend our study to the simpler alloy and the more complex alloy steels. A great many details of foundry technique quite apart from the satisfactory manufacture of the metal in the furnace are involved in the production of alloy steel castings that will render satisfactory service. Certain alloying elements have peculiar characteristics that must be taken into consideration in numerous operations essential to casting manufacture. As the production of alloy cast steels increases proportionately in any shop, experience is acquired, having its inevitable and invaluable influence on the satisfactory performance of the product when it is put into service.

Reference made to chemical composition as being no more than one of several important factors makes it appropriate to mention the fact, appreciated by foundrymen but not always understood by consumers, that the behavior of the metal in a laboratory specimen may be far different from that of the same steel in a member of a casting, due to many possible causes, one

of which is design, as determined by the user, and many of which are matters of foundry technique as determined by the maker.

At this time when the manufacture of alloy cast steels is rapidly increasing, with prospects for extending production yearly, accurate, representative data as to the performance of the many varieties of special steels used for castings are highly desirable. Through no other medium can test results be established as truly representative of the several grades of metal used for the product. The author has attempted to make a contribution for that purpose, with no intention of doing more than showing typical results obtained in one plant. He believes the potential value of his effort, made in the spirit of co-operation, will be chiefly dependent on the stimulating effect it might help to exert on other steel foundrymen to publish information on this subject, following an example for which the author claims no originality.

Foreman Training

BY A. D. LYNCH,* MANSFIELD, OHIO

A comprehensive discussion of the subject of foremanship and foremanship training must, we believe, start with an analysis of the duties and responsibilities of foremanship in modern industrial procedure and an analysis of the attributes and characteristics essential in the individual foreman or candidate for foremanship if he is to be amenable to training and if he is to have the capacities and abilities requisite to a full foremanship performance.

If we can agree that certain specific responsibilities and duties belong to a foreman's job and if it can be shown that the average individual who has attained foremanship or who is striving for foremanship has not reached that position, or is not approaching it through channels of experience that will fully prepare him for a complete fulfillment of these duties and responsibilities, then we can recognize the necessity for training of some sort and can by analysis determine the character and method of providing the needed training.

Qualities Essential in a Foreman

Having this picture of the responsibilities of foremanship we can also determine fairly accurately the qualities or attributes essential in the individual who is to fully meet them. We should

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Discussion of this paper begins on page 610.

recognize the fact that one not possessing these qualifications to a large degree cannot hope to function fully as a foreman and that time and effort spent in training prospects lacking in the fundamental qualifications is largely wasted. If you proposed to train a string of horses to enter in the races you would start to train only those that by breeding and pedigree seemed to offer possibilities of speed. We should use an equal amount of judgment in checking candidates for the foremanship derby.

Stated broadly there are two responsibilities of foremanship:

1. Getting out the product.
2. Handling people.

The first of these is really inclusive of the second, for the second is necessary in order to accomplish the first. We will, however, progress in a more orderly manner in this discussion by considering them separately.

Getting Out Product

In getting out the product the foreman is responsible for:

1. Maintaining the quality of the product.
2. Cost, direct and indirect.
3. Schedules.
4. Maintenance of plant and equipment.
5. Cleanliness and orderliness.
6. Safety in operation.
7. Economy in operation.

Undoubtedly these things could be stated differently and more than these seven could be listed as specific responsibilities. These, however, are comprehensive and a short discussion of each as a function of foremanship is worth while.

Quality of Product

Management realizes fully the need of quality in product if it is to render through that product the service essential to the maintenance of sales volume. Rigid inspection of process and finished materials may be a sufficient guarantee of the desired quality. Inspection, however, cannot completely safeguard quality and can only secure results at the cost of rejected material,

unless the foreman in direct charge of processes knows thoroughly the standard of quality desired, the service requirements of the product he is making, the physical properties and limitations of the materials he is using, and the proper methods of fabrication, and is constantly alert to maintain the quality of his product. Intelligent supervision during process is the only sure safeguard of quality.

Cost Information

Cost systems and properly managed cost departments are not responsible for costs. The best they can do is to accurately collect and report facts. The foreman on the job determines your costs. Direct labor costs reflect the efficiency of his management even though your records may show that direct labor was paid 100 per cent on a piece work basis. Indirect cost, non-productive labor, supplies, maintenance of equipment, spoilage of material, rejections, and many other items affecting final cost, can be properly controlled only when the foreman understands *costs*, knows his own *costs* and intelligently accepts *cost of product* as one of his responsibilities.

Planning

Proper planning of plant and departmental activities is necessary to economical production and reliable information on which to base delivery dates. The best efforts of the planning or production department can accomplish little, however, unless the foreman knows the capacities of his men and machines, and unless he plans intelligently his program in meeting the schedule of the planning department.

Maintenance of Plant

The foreman of an average department in modern industry is in direct charge of machinery, tools or equipment representing a considerable investment, in many cases, many thousands of dollars. The manner in which such equipment is used, instructions to operators, decisions as to where and how to repair or alter will materially affect the maintenance cost and the inventory value of such equipment, and these things must all be supervised and decided by the foreman in charge.

Plant Housekeeping

Good housekeeping, a clean and orderly shop, is recognized as an essential to economic production of quality materials. Good, careful interested workers are not found in dirty, disorderly shops. The understanding of these things by a foreman and his own sense of orderliness will largely determine the condition of a shop or department. Management may wish to have, and make rules to obtain, a clean and orderly shop. Only the foreman is in position to really get it.

Safety

The foreman is responsible for accidents occurring in his department. If this theory is not accepted in any plant or department, then that plant or department is having too many accidents. It is only when the foreman accepts this responsibility that accident prevention can secure results. The foreman is directly responsible for the physical condition of his department from a safety standpoint, and for the instruction and supervision of his workers. He is your key man in safety.

Economy of Operation

The general business management and economy in operation of a department is a foremanship responsibility. Proper methods, elimination of waste of time, materials, supplies and services all depend on the supervision and intelligent interest of the individual directly in charge, the foreman.

These do not constitute all the responsibilities of foremanship in getting out the product but will suffice in connection with his responsibilities in other directions to show that management cannot expect a full performance of such duties without some special training or preparation to fit the individual to meet them.

What the Foreman Must Do in Handling Workers

In handling people the foreman's job is to build up around himself in his department a group of people competent in every way to do the work required of the department and to know and supervise this group and its work in such a manner that he will meet the desires of his management on quantity, quality and cost of product and have a friendly, interested, stable group of workers. To do this he must be able to—

1. Place his men according to their ability and capacity.
2. Give instructions properly.
3. Manage individual workers according to their temperament.
4. Delegate work and responsibility correctly and supervise it properly.
5. Set a proper example for his people.
6. Compensate fairly and proportionately.
7. Secure and hold the friendship and respect of his people.

Placing Workers

Placing individual workers according to their ability and capacity may require much study of people and many changes in distribution of work, but the results possible of accomplishment by a successful following of such a program make the effort worth while. If men are not so placed management and the business loses by not receiving the full efficiency of the individual, and the man himself will eventually leave or become an indifferent worker, for none of us can, for long, take a real interest in, or find happiness, in doing work for which we are not fitted and which we cannot do well. If a foreman has workers who are not fitted for the particular work he has them doing, he should in fairness to such worker and without consideration of the monetary loss to the business, see to it that their work is changed.

Proper Instruction to Workers

A foreman's position presupposes his responsibility for the kind of work done by those working for him. If you eliminate

the losses suffered in industry in processing materials that are due to defective raw materials and wrong equipment or tools you will find that these things cause only a small percentage of losses and that the major portion of such losses are due to carelessness or inefficiency on the part of someone. If you analyze these losses you will find that almost invariably there was lack of proper instructions somewhere. In the assignment of work a foreman must know first the job, and second the worker, sufficiently well that he can instruct properly as to methods, and he must know when he has given the type of instructions necessary for the individual who is to do the work. Failure to do both properly, is certain to result in indifferent work and in a resentful, disgruntled workman, and the fault lies with the foreman, not with the worker.

Managing Individuals

Manage the individual according to his temperament. We all know from our own experience how differently we are affected by our contacts with different people. Some people we know can say things to us or do things to us without offense, that would be deeply resented if said or done by another. This is because no two people are exactly alike in disposition and general make up. This being true the foreman must study two things, first the proper method of handling each individual and second the effect of his own personality on the worker. It is never necessary in the handling of people to be abusive or sarcastic, or to do the thing that will hurt or humiliate. If a foreman does these things he has only erected one additional barrier to proper future relations. When criticism or correction is needed a foreman must not avoid the issue but he must do these things in a proper manner. When commendation or praise has been earned they should not be withheld, but they should be given in such a manner as to stimulate further endeavor and not in a way that might create a feeling of self sufficiency that would lead to a relaxation of effort.

Delegating Work

A foreman, if he is to develop his executive capacity and if he is to have the time necessary to plan his work, must judge his men, watch his product, and make the proper and necessary contacts with his superiors in the organization and must learn to delegate many of the details of the work of his department to others. The question of what functions or duties may be safely delegated, and of a proper supervision of them thereafter, the ability to delegate responsibility along with work and maintain the proper contact with the work is of vital importance to successful foremanship and is too frequently not understood by foremen.

Foremen to Set Example

Set a good example. Very few of us realize to what extent our actions and conduct are observed by those who work for us. If a foreman's conduct is such as to deserve criticism he can do nothing if he finds his people making such criticisms, and he will find it hard to make the necessary corrections if he should find his people copying his conduct. If he expects those who work with him and for him to observe the rules necessary to the proper operation of his department, then he must observe them himself. If he expects them to be clean and orderly about their work and their personal appearance then he must be so himself. He must maintain a proper dignity on the job. By this I do not mean, to use a slang expression, that he should "High Hat" anyone. He should be agreeable and friendly with his workers but never to the extent that he loses his authority over them.

Problem of Compensation

Perhaps the most difficult problem a foreman has in handling his workers is the one of compensation. There are so many factors affecting wage rates, outside the control of the management of any individual business, that cannot be disregarded if the

business is to remain on a sound economic basis that it is difficult to give all these factors their proper consideration and at the same time satisfy a group of workers that their wages are fair. It is human nature and to be expected that workers in general will desire more than they have of this world's goods and that they should expect to obtain this increase in well being from their efforts where they work. It is the foreman's job to see that all his rates are in keeping with the policy of his management and that there are no discrepancies, high or low spots, as between individuals or jobs that are not fully warranted. It is no easy matter to judge values and interpret them into terms of compensation. It is least difficult where the operations done are the same or similar enough to make comparisons easy. With a greater variety of work and the necessity of judging between the compensable value of skill as compared to physical ability, or intense application as compared to high speed on routine work, the task is more difficult. Piece work or other wage incentive plans on a proper study of operations and fairly fixed and maintained will do much to help a foreman solve the problem of compensation.

*Friendship and Respect of His Workers Foreman's
Greatest Asset*

In all of his relations with people a foreman will find the friendship and respect of his people his greatest asset in meeting his problems. He can only have this friendship by being a real friend to his people and he can only have their respect when his conduct on the job and in his private life off the job is such as to win and hold the respect not only of his people but of all those with whom he makes contact. It requires real character to be a real leader such as present day foremanship demands.

We have taken considerable time to outline the duties and responsibilities of foremanship. No claim is made that the list given is complete, and we are confident that some exceptions may be taken to even those things that have been listed. We are certain, however, that real foremanship, foremanship that will relieve superintendents and factory managers of detail work and give them time for the larger problems of their business, fore-

manship that will meet the needs of industry in the years just ahead, must meet all these responsibilities and more.

Qualifications of Today's Foremen

What are the qualifications and what has been the training of the average individual who is in a foremanship position today or who may be inducted into foremanship? Where does he come from and how does he attain foremanship? By far the greater part of the foremen in industry came up from the ranks through successive steps to their present position and this is as it should be, and should continue to be. They were, however, selected for their position largely because of one specific qualification, skill and knowledge of the work to be done in the particular department for which they were selected. How are these men to know the full requirements of their new job, and how are they to fit themselves to meet such requirements? Is it reasonable to expect any foreman to know all these things when it is only within recent years that only a part of management has recognized many of them? Obviously it is *management's* job to show its foremen a true picture of their job and train them to fill that job properly.

Recognition of Need of Training Has Come from Foremen and Management

The past few years have shown a widespread recognition of the necessity of foreman training. It has come from two sources and from two different but perfectly logical causes. In some places foreman training has been initiated and fostered by management where those in charge recognized the need of more efficiency in operation and decided that better foremanship was one means of securing it. In other places it has been sought by the foreman when he recognized the need of better personal equipment for his job if he were to advance or even hold his position.

Foremen's Clubs

The foreman's club has been the logical development to meet the need. When recognition of the need came from management the club usually included only foremen from the one plant. When

it came from foremen, the larger group comprising foremen from several plants or a city wide group usually resulted and these clubs have been formed into state and national organizations for foreman training. These larger clubs cannot give all that is needed. The contact with other foremen will help. The discussion of the general problems of foremanship will help. The individual foreman, however, needs specific instruction and training along practical lines that he can use on his own job and that only his own management is in position to give him.

Foreman Training a Problem of Management

The problem of foreman training is the problem of the management of every shop or plant. Regardless of training along these lines received in city, state or national clubs or by study of correspondence school or university extension courses in foremanship there is still need of training by management.

This is not difficult and does not present any problems that the average plant, large or small, cannot readily meet. The set up for such training should include foremen, assistant foremen, instructors or anyone in the organization having direct supervisory control of people or work.

Meetings should be held after working hours. To prevent repetition of subject matter, all should be present, and to hold such meetings during working hours would leave all departments without supervision. The most satisfactory arrangement is to meet for dinner and have the business session immediately following. If the plant does not have a cafeteria, making such a meeting possible at the plant, arrangements for dinner and meeting can be made outside the plant. It is worth the cost for management to provide a proper meeting place and a good dinner to start each meeting. Monthly meetings, except during the summer months, on a fixed date, as for example the first Monday in each month, will be found the most satisfactory.

Meetings at the start should be conducted by the executives, preferably the general manager or factory manager, and the program from the start should be one of education in the business

facts and policies of the company. Foremen, if they are to have a real interest in their work and if they are to be able to carry out the policies of management intelligently, are entitled to know all the facts of the business, and must know what the management's policies are. Several meetings can be very profitably spent on these things. Most managers will find many things that were very definitely fixed in their own minds as to policy but on which no open expression of policy had been given to foremen or people.

When this phase of the program is completed sub-executives would in turn explain the workings and policies of their departments; the manufacturing superintendent, production manager, cost manager, personnel manager, technical and engineering department heads, etc., each giving the foremen all the facts and figures of his department. This may seem revolutionary to some managements but unless you are willing to give these things to your foremen you cannot hope to have them work intelligently. A foreman cannot be responsible for costs unless he knows how your costs are made up and knows everything that goes into them and why. He will not handle people properly until definite company policies have been established for personnel problems and until he has been shown the necessity of observing these policies.

When this phase of the program has been completed you are ready to make the club actually a foreman's club. Use the daily problems that arise in the plant as subject matter and your foremen as speakers or in round table discussion and you will find that participation of this sort will develop many desirable qualities in your foremen. There will continually be things that the higher executives should bring before the club, changes in policies, changing business conditions and their effect on your local situation and many other things which can be discussed and make possible regular meetings with something interesting and instructive always available for the program.

The Past and Future Trends

The past 20 or 25 years have witnessed a phenomenal increase in prosperity, due largely to increased productiveness on the part of workers and this in turn is due largely to development of

improved machinery and mechanical devices and to a wider distribution and increased use of power. America has led the world in this increase in productivity, in the development of machinery and in the use of power and therefore in prosperity and in the standard of living enjoyed by her people.

Power development, and distribution and increased use of power is the outstanding feature of industrial development in many other countries at present. Our machinery and mechanical improvements are or soon will be in use everywhere. How are we to maintain our leadership? Along with the evidence that world competition will more and more use our methods and our machinery we must recognize that although the limit has not been reached in mechanical development or power distribution and use it is practically certain that the rates of development along these lines will not be as great in the next generation as they have in the past. Where then is industry and business to get the impetus that will make possible continued growth and increasing prosperity? We must go on for if we do not go forward we will inevitably lose our margin of advantage in the world picture.

The impetus that is necessary to maintain our place in the coming years can and must come from increased interest and more intelligence and more cooperation on the part of people and this is only going to come in proportion as industrial and business managements train and educate not only their foremen but their workers as well in the fundamental facts and requirements of their business and show them their place in the picture so clearly that they will be able and willing to give a more intelligent and interested effort in their work.

Management that fails to recognize these things and fails to train foremen and workers will in the next few years find difficulty in meeting the competition that will be theirs.

Practical Aspects of White-Fracture Malleable

BY D. P. FORBES,* ROCKFORD, ILL.

The purpose of this paper is: (1) to describe what is meant by white fracture malleable, (2) to explain why the fracture is white, (3) to describe the conditions under which it occurs, (4) to suggest how it may be avoided or corrected, and (5) to offer a possible metallurgical explanation of the phenomenon.

1. *White-Fracture Malleable*

In this paper reference is made only to the "American black-heart malleable" process whereby white cast iron is annealed in such a way as to leave a product consisting of temper carbon nodules scattered throughout a matrix of ferrite or carbon-free iron. This is not to be confused with white-heart malleable made by decarburizing white cast iron in an oxidizing packing material by annealing at high temperature.

The normal fracture of black-heart malleable is dark gray with a silky texture and with a narrow white crystalline band on the compression side of the fracture.

If the malleable is not correctly annealed it will have a white sparkling fracture due to the presence of non-ductile pearlite or

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Discussion of this paper will be found on page 657.

cementite mixed with the ferrite of the matrix. Or if the analysis is "off," and under certain conditions of anneal, a "picture frame" fracture may result which has a normal black core, and a white sparkling band around the outside, which is often in turn surrounded by a light gray decarburized border.

But in these latter cases, combined carbon is always found upon analysis and the metal is hard to machine, non-ductile and often of high tensile strength.

The material with which we are dealing in this paper is moderately ductile, contains practically no combined carbon, is easily machined, and breaks with a white crystalline fracture throughout.

Under the microscope, a prepared section appears to be identical with normal malleable. The sure test for white fracture malleable is to warm a sample slightly, say to 200 degrees Fahr., at which temperature a fresh fracture will be largely black with a sparkling band on the compression side of the fracture slightly wider than usual. The material at this temperature will be very ductile and tough.

2. Why the Fracture Is White

A characteristic of ferrite or carbon-free iron is its ductility. Therefore when normal malleable is broken the individual crystals of ferrite are elongated until they break off in the shape of points or spines which have no smooth reflecting surfaces to give a steely appearance. The dark gray appearance is due to the graphite particles exposed at the time of fracture. The ferrite crystals of malleable are held together by an "inter-crystalline cement" which is apparently stronger than the ferrite itself. Not much is known about this "cement" except that it is more easily attacked by etching solutions than the ferrite crystals and therefore shows up under the microscope as a narrow groove at the crystal boundaries.

When "white-fracture" malleable is broken, the microscope shows that the line of fracture, instead of going through the ferrite, tends to follow the crystal boundaries, exposing the smooth surfaces of the crystals and giving a steely appearance. This is called an inter-crystalline fracture as distinguished from

the trans-crystalline fracture of normal malleable. Even if only a portion of the fracture is of the inter-crystalline variety, the appearance of the fracture is distinctly steely.

Apparently, therefore, white fracture malleable is due either to the weakness or brittleness of the inter-crystalline cement at low temperatures or else to a strengthening of ferrite at low temperatures making it stronger than the "cement." As it is probable that this "cement" is amorphous in nature, and as amorphous materials generally become more brittle as the temperature is lowered, it is probable that the cause for the white fracture can be attributed to conditions at the crystal boundaries.

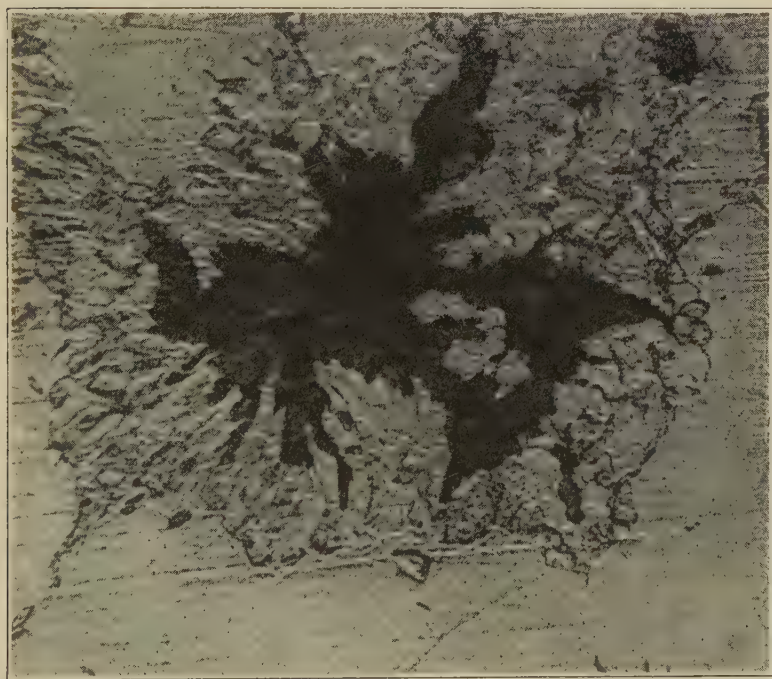


FIG. 1—PHOTOMICROGRAPH AT 800X SHOWING THE PECULIAR FORMATION OF TEMPER CARBON USUALLY FOUND IN WHITE FRACTURE MALLEABLE—THE SHAPE IS INDICATIVE OF A HIGH ANNEALING TEMPERATURE—ETCHED WITH 4% NITRIC ACID IN ALCOHOL.

3. What Conditions Favor White Fracture

The points covered in this section are largely the result of observations in the laboratory of the foundry with which the writer is connected and unfortunately do not afford an exhaustive survey of the whole field. The occurrence of the phenomenon is spasmodic and it is costly to make deliberate attempts to produce white fracture material.

If material likely to cause white fracture is annealed in a single annealing oven, the castings when taken from the oven will not necessarily all be of white fracture when cold; and some castings may be white fracture at one end and normal at the other. This shows the uncertainty and delicacy of the phenomenon.

Analysis Has a Bearing

We have noted, however, that we have not encountered white fracture when the silicon content of the white iron was below 1.00 per cent or when the phosphorous content was below 0.17 per cent, and that we have almost always found examples coming from heats with the silicon content 1.10 per cent or over and a phosphorus of 0.20 per cent or over.

Heat Treatment Has a Bearing

We have practically never encountered white fracture iron from a muffle oven where the maximum temperature is 1525 degrees Fahr. and where cooling is extremely slow at about 4 degrees per hour down to 250 degrees when the oven is dumped.

In pot type ovens where the maximum temperature is 1600 degrees Fahr. and where cooling is at the rate of 12 degrees per hour, metal with a tendency toward white fracture may be found if the oven is allowed to cool to 250 degrees before dumping. In fact, if the castings are dumped at about 850 degrees the condition is most noticeable.

In our annealing room our practice for years has been to dump our pot type ovens at about 1000 to 1100 degrees in order to save time and expedite deliveries. Under these conditions white fracture iron was extremely rare. In fact, the first large

quantity of white fracture castings we encountered resulted from the ovens being allowed to cool to room temperature during a shut down from Christmas to New Year. Naturally we do not permit our pot ovens to cool below 1000 degrees in our present practice.

But the surest way to develop a white fracture in metal having a tendency in that direction, is to heat the casting, after annealing, up to 850 degrees and then quench in air or water. This is what happens in the hot dip galvanizing process and gives rise to galvanizing embrittlement. Castings which after annealing do not show white fracture even at low temperature may become white fracture castings after galvanizing.



FIG. 2—PHOTOMICROGRAPH AT 1700X SHOWING THREE OF THE CRYSTALS FOUND AT THE GRAIN BOUNDARIES OF THE FERRITE IN WHITE FRACTURE MALLEABLE—THESE CRYSTALS ARE EXTREMELY SMALL, THE LARGER ONE SHOWN IN THE MICROGRAPH BEING MUCH LARGER THAN THE AVERAGE.

There appears to be at 850 degrees a critical temperature from which castings must not be cooled quickly if white fracture is to be avoided.

Furnace Operation Is a Factor

We have observed also that melting furnace operation has a bearing on the occurrence of white fracture castings. When our furnaces are operating normally white fracture castings are very rare. When we encounter a quantity of white fracture metal we can usually trace it to a single heat in which the furnace operation was abnormal. This usually took the form of excessive oxidation of the charge, or slow melting or slow heating up after the bath was liquid.

Whenever we have encountered any quantity of white fracture iron we have usually found that we also had an abnormal amount of scrap from shrunk and cracked castings.

4. What Remedies Are There?

The best way to avoid white fracture malleable is to avoid the conditions under which it is formed.

First, the analysis should be under 1.00 per cent silicon and 0.17 phosphorus. The lower the better.

Second, the melting operation should be normal.

Third, excessively high annealing temperatures should be avoided and the oven should be "pulled" at over 1000 degrees.

Fourth, the castings should not be reheated to 850 degrees.

If white fracture iron is encountered, it can be corrected by a patented process called the "Flecto Process," whereby the castings are reheated to 1200 degrees and quickly cooled through the 850-degree range. This will make the castings normal again even to the extent of being able to withstand the galvanizing process. It is our understanding, although not supported by our own observations, that prolonged heating, say for 10 or 12 hours at 850 degrees, will cause the phenomenon to reappear.

5. A Possible Theory

Microscopic examination at high magnifications of white fracture metal indicate the presence at the grain boundaries of

globular inclusions of material dissimilar to ferrite. The fact that these areas are found only at the grain boundaries of the ferrite would indicate that this material did not have a higher melting point than the material which surrounded it or, in other words, was formed after the ferrite. This is the opposite from the case of manganese sulphide which is formed in the solid phase at high temperature and therefore is found at any point in the micro-structure, such as in the center of a ferrite grain and only accidentally at the grain boundaries.

To draw a hasty conclusion based upon the facts as we have noted them, we find that phosphorus when present in iron-carbon alloys is soluble in ferrite but insoluble in iron containing combined carbon. The tendency when iron, phosphorus and combined carbon are together is to form a ternary eutectic with a low melting point.

When malleable is at the annealing temperature and the anneal is almost completed it consists of austenite and graphite. As the austenite contains combined carbon, any phosphorus is out of solution and at the austenite grain boundaries. When the metal reaches the critical point in cooling the austenite is presumably almost carbon-free and the ternary eutectic of phosphorus will disappear and the phosphorus be dissolved in the gamma iron as iron phosphide, and will remain in solution in the ferrite after complete cooling.

Under certain conditions of high temperature it is possible that the phosphide eutectic will segregate into larger areas than normal and in the cooling time at the critical point will not be completely dissolved by the carbon free iron and will remain to weaken the grain boundaries.

Similarly the presence of high silicon may have a bearing on the solubility of phosphorus in iron, just as it has on iron carbide.

To fix the blame entirely on the presence of phosphorus at the grain boundaries it would be necessary to show that some form of phosphorus would be weak and brittle when cold; that is,

at about 50 degrees Fahr., and strong and ductile at 250 degrees Fahr. Also that quick chilling from 1200 degrees Fahr. would lower the embrittlement temperature to a point well below zero degrees and that heat treatment at 850 degrees would favor embrittlement. We are not able to shed any light on this subject as our research ended when we found means of avoiding the trouble. The subject is one which deserves investigation in a research laboratory rather than in a plant control laboratory.

High-Test Gray Cast Iron—European Developments

BY EDWARD E. MARBAKER,* PH.D., PITTSBURGH, PA.

Introduction

While the manufacture of gray iron castings is one of our oldest industries, it is only within recent years that serious attempts have been made to improve its properties. This improvement has been fostered by the commercial necessity for better castings, and by the increased knowledge of the metallurgy of steel. It has long been known that the strongest steel exhibit a pearlitic structure which appears under favorable conditions when the carbon content is 0.90 per cent. It has been found that the basic ground-mass in cast iron is also pearlitic, but that it can be brought out only under very carefully controlled conditions. Cast iron also contains much higher contents of carbon than steel, and a part of this is combined with iron, the remainder existing as graphite which occurs generally in the form of plates. The structure of cast iron is therefore not as continuous as that of steel, and the fact that it is not as strong is thereby accounted for. It was necessary for investigators to discover means for controlling the structure of the ground-mass, and the form and distribution of the graphitic carbon in order to obtain cast iron of high strength and with other improved qualities.

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Discussion of this paper begins on page 729.

Goerens showed in 1906 that cast iron in order to possess the best strength properties should have a pearlitic structure. The examination of many castings served to prove his contention, but no method of insuring the desired structure in every casting had been worked out. It was also shown that it would be highly desirable to change the form and distribution of the graphite. The improved strength of malleable iron due to the presence of carbon in the form of fine grains, called temper carbon, demonstrates this. Since 1906 many attempts have been made to follow out the ideas of Goerens systematically, and there are now available a considerable number of methods for the manufacture of cast iron possessing improved properties, which has come to be known as high-test cast iron.

The methods now known may be divided roughly into six classes, as follows:

1. Decrease of carbon content.
2. Control of cooling rate after casting.
3. Reduction of particle size of graphite and improvement of distribution.
 - a. Superheating.
 - b. Rapid cooling of high silicon iron.
 - c. Treatment with calcium silicide.
4. Alloying with elements such as nickel and chromium.
5. Agitation of molten iron.
6. Eutectic cast iron.

Each of these groups will now be considered briefly.

1. Decrease of Carbon Content

Since steel contains no graphite and is strong, it is obvious that attempts should have been made to decrease the carbon content of cast iron. This has generally been attained by large steel additions to the charge, and the resulting material has been called semi-steel, and synthetic cast iron. No special apparatus is required for melting, but the cupola must be operated very efficiently from the standpoint of combustion in order to attain the requisite temperature, since the steel mix melts at a higher temperature than

ordinary cast iron. Because of this fact the electric furnace has had a wide application in this field. It has another advantage in that the carbon pick-up, which must be taken into account in cupola melting, is obviated. In general the results of melting in the electric furnace have been better than those attained in cupola melting, and this may be attributed to the higher superheat which is attainable.

The investigations of Wüst have shown that the results are best when the carbon content is between 2.2 and 3.0 per cent, silicon 2.2 and 1.2 per cent, and manganese 1.0 per cent. The structure consists mainly of pure pearlite with fine and scanty graphite interspersions. As the carbon is decreased the manganese should increase.

Technically this theory is represented by semi-steel, the Stern-guss of Krupp, Emmel's process, Meehanite, and the Corsalli process. The last mentioned product also falls into the classification of iron produced by superheating. The technology of semi-steel has been worked out to a great extent in this country, as is also the case with Meehanite which is made by the addition of calcium silicide to the molten iron. The Krupp, Emmel and Corsalli processes were worked out in Germany and have been widely discussed in the literature. The analysis and properties of the cast iron made by these methods is shown in Table 1.

Table 1

	Total Carbon, per cent	Silicon, per cent	Manga- nese, per cent	Phosphor- us, per cent	Sulphur, per cent	Modulus of Rupture, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.
Semi-Steel:							
Cupola (25% Steel)	3.11	2.24	0.44	0.48	0.08	56,200	33,770
Electric Furnace...	3.12	2.23	0.64	0.42	0.042	69,900	.....
Krupp							
Stern-guss	2.4-2.7	1.66-2.33	0.86-1.46	0.11-0.24	0.08-0.13	91,000	50,000
Emmel							
(50% Steel)	2.64	2.14	1.37	0.25	0.16	.....	52,500
Meehanite...	2.4-2.7	1.30-1.80	0.50-1.00	0.12-0.20	0.08-0.14	88,000	.....
Corsalli....	2.73	2.20	1.34	0.26	0.11	83,800	52,100

2. Control of Cooling Rate After Casting

Diefenthaler and Sipp followed systematically the ideas of Goerens and sought to produce a cast iron which would always

exhibit an all-pearlitic structure regardless of thickness of section. In 1916 the first of the series of patents covering pearlitic cast iron was granted to them. The process covers the use of a low-silicon mixture, and the cooling of the castings in previously heated molds in accordance with a definite schedule depending upon the thickness of section. The principal characteristic of this iron is that if it were cooled normally it would solidify as white iron, but when cooled in preheated molds it solidifies as gray iron. The structure is completely pearlitic, and the graphite appears in small flakes, uniformly distributed. In general a normal cupola charge is used which is so arranged that the graphite formation is stimulated as little as possible. The total content of carbon and silicon is 4 per cent ($C \leq 3.5\%$, $Si \leq 1.5\%$). The cooling rate required by different wall thicknesses is obtained by heating the molds to experimentally determined temperatures. For very thin walls, which will cool too quickly, a softer charge is used in which the sum of the carbon and silicon is 4.6 per cent ($C \leq 3.5\%$, $Si \leq 1.12\%$), and for thick walls a harder charge in which the sum of the carbon and silicon is 3.4 per cent or less ($C \leq 2.9\%$, $Si \leq 0.9\%$). Curves showing the required mold temperatures for all compositions and wall thicknesses were plotted. It was stipulated that the pouring temperature should be 540 degrees Fahr. above the melting point of the iron.

The analysis and properties of cast iron made by this method which is usually called the Lanz-Perlit process are as follows:

Total carbon	3.25%
Silicon	1.11
Manganese	0.79
Phosphorus	0.40
Sulphur	0.15

1. High modulus of rupture (40,000 to 80,000 pounds per square inch) and tensile strength (30,000 to 50,000 pounds per square inch); toughness.
2. High resistance to impact.
3. Moderate hardness and high degree of machinability.
4. Resistance to abrasion.
5. Fine, dense structure which is unaffected by temperature changes.

The Lanz process is complicated and requires much care in manipulation, but the results appear to justify it.

Since the preheating of molds and the very careful control of the mixture is troublesome, later investigators have tried to show that the all-pearlitic structure can be obtained by less cumbersome methods. Maurer and Emmel show that with similar composition of materials and without preheating of molds, the pearlitic structure can be obtained within the widest limits of casting section, and the structure is uniform. It appears from this that some other factor than the mere preheating of molds is responsible. In the case of Krupp and Emmel iron, which are cast at much higher temperatures than Lanz "Perlit" iron, it appears that the superheating may be the effective agency, and it would seem that essentially the Lanz process is a form of heat treatment. It is certain that the castings made by the processes so far mentioned have much the same composition and properties, and the structure is all-pearlitic in each case.

3. *Reduction of Particle Size of Graphite and Improvement of Distribution*

The properties of malleable cast iron have long been attributed to the finely divided form and the uniform distribution of the graphite (temper carbon), and investigators naturally reasoned that the production of gray cast iron containing the graphite in an analogous form would result in an improvement of properties. Goerens declared that the form of graphite theoretically can be influenced without resorting to heat treatment as in the case of malleable iron. There are three ways in which this can be carried out:

- a. Superheating of the molten iron.
- b. Rapid cooling of molten high silicon iron.
- c. Treatment of molten metal with calcium silicide.

Superheating of the Molten Iron. Piwowarsky and Hane-mann have shown that superheating influences the form and quantity of graphite. With rising temperature of superheat the graphite grains become finer and finer with the temper-carbon-like graphite

eutectic as the limit. The formation of iron carbide (cementite) increases and then decreases as the temperature rises. With material containing 0.06 per cent silicon the transition point lies at 2730 degrees Fahr. Below this temperature the melt has a tendency to solidify carbidic while above it the tendency is toward increased graphite separation. The transition point is not changed by increasing the time of heating for the same analysis, but at lower temperatures continued heating acts in the same way on carbide formation as temperature elevation. An increase of silicon from 0.06 to 2.35 per cent changed the transition temperature from 2730 to 2550 degrees Fahr. This phenomenon has given rise to the theory that the usual non-uniformity of the metal and the difficulty in reproducing results in the foundry are due to the fact that the iron is not heated to a sufficiently high temperature to bring about the complete solution of the carbon and to attain the degree of homogeneity of the melt which is desirable. When, however, the iron is superheated, a homogeneous melt is produced and on cooling the crystallization of graphite proceeds from tiny nuclei and the resulting crystals are small and evenly distributed. The degree of superheat determines the amount and fineness of the graphite present. On cooling from high temperatures 2700 to 3100 degrees Fahr. the graphite is deposited in very fine crystals of the temper-carbon form, and the properties of the metal are thereby greatly improved. The rate of cooling should be slow enough to allow the solid solutions to become saturated, and this insures equilibrium in the finished casting.

The superheating may be carried out in the standard cupola by decreasing the melting ratio, but here care must be taken that too much carbon is not absorbed from the coke. The Emmel process depends to some extent upon superheating of the molten iron in the cupola, and the specification of the patent includes definite directions for the operation of the cupola. It would seem to be preferable to use one of the many types of forehearth which are heated independently since in this way the carbon content can be controlled. The Wüst oil-fired furnace, which is a combination of stack and air-furnace hearth, has been successfully used because

no coke is used and there is little chance for the metal to pick up carbon. The electric furnace has also shown successful results, especially when the duplexing process (melting in the cupola and superheating in the electric furnace) is used. It is probable that the superior properties of semi-steel are due to superheating in addition to the benefit which is derived from the low carbon content.

The Corsalli process affords another means of obtaining superheat in the standard cupola. Extremely high blast pressures are used and the silicon and manganese which are burned out are replaced by the introduction of ferro-alloys into the melting zone by means of a specially constructed apparatus affixed to the cupola and connecting the charging door with the melting zone directly.

The analysis and properties of the high-test gray cast iron produced by superheating are shown in Table 2.

Table 2

	Total Carbon, per cent	Sili- con, per cent	Manga- nese, per cent	Phos- phorus, per cent	Sul- phur, per cent	Modulus of Rupture, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Transverse Strength, lbs. per sq. in.
Cupola (Emmel)	2.64	2.14	1.37	0.25	0.16	.....	52,500	....
Electric Furnace	3.12	2.23	0.64	0.42	0.04	69,900	.....	4,480
Duplex Process	3.33	2.01	0.54	0.55	0.03	.....	.....	4,287
Corsalli Process	2.73	2.20	1.34	0.26	0.11	83,760	52,100	....
Wüst Oil-Fired Furnace	2.70	1.67	0.96	0.39	0.07	78,500	47,000	....
Cupola (Semi- Steel)	3.11	2.24	0.44	0.48	0.08	56,200	33,770	....

Rapid Cooling of High Silicon Iron—Schüz Graphite Eutectic.

Schüz proposes that the structure of the casting be controlled by utilizing a mixture of definite composition and pouring into chills. The structure is not pearlitic, but a eutectic of ferrite and graphite. This iron is stated to possess a stable structure and to be constant in volume at high temperatures. The iron contains 3.6 per cent carbon and 3.3 per cent silicon. The modulus of rupture was 120,000 pounds per square inch, and the tensile strength 51,500 pounds per square inch. The final product has a structure and properties comparable to malleable iron, but it is to be noted that the silicon is very high.

Treatment with Calcium Silicide. In this process by which a special cast iron called Meehanite is produced, the mixture is melted in the cupola, air furnace, or in the electric furnace, and calcium silicide is added in the ladle. The product exhibits structure similar to that of Krupp Sternguss, or Emmel iron. The modulus of rupture extends from 83,500 to 100,000 pounds per square inch. The carbon content is 2.2 to 2.7 per cent and the silicon 1.03 to 1.80 per cent depending upon the type of furnace used for melting.

This type of high-test cast iron is an American product, and as such its discussion is out of place in this paper. It is merely mentioned as an example of a method different from any yet described by which high-test cast iron may be produced.

4. Alloying with Elements Such as Nickel and Chromium

The improvements in the properties of gray cast iron brought about by the addition of alloying elements to iron melted in the cupola have been worked out principally in this country, although a great deal of corroborative work has been carried on in Germany and in England under the auspices of the British Cast Iron Research Association. Such alloy cast irons do not depend particularly upon the formation of perlitic structure, but more upon the control of the graphite form and distribution. This method is mentioned only in passing because being in general an American development, it has no real place in this paper.

5. Agitation of Molten Iron in the Forehearth

Considerable attention has been given in the literature to the process of agitating molten cast iron in the forehearth which was worked out by the German, Deschene. This method of producing high-test gray cast iron differs materially from the other processes which have been described. The essential feature of the process is a forehearth which is so arranged that the metal which is drawn from the standard cupola, is subjected to violent jolting. In the other process, the cast iron is improved by chemical and thermal means; in this process the operation is entirely mechanical. The value of the method lies in the fact that the molten iron is thor-

oughly mixed, gases are eliminated, the sulphur is rendered innocuous by more perfect slagging, and the carbon is brought into more nearly complete solution. The process is worked out more or less independently of the mixture charged into the cupola.

It is stated that whether the iron contains 3.2 or 3.6 per cent carbon, 1.6 or 2.6 silicon, the following properties are obtainable with the normal casting temperature of 2450 to 2550 degrees Fahr.; tensile strength 42,000 to 57,000 pounds per square inch: modulus of rupture 71,000 to 85,000 pounds per square inch. The Brinell hardness varies between 180 and 240. Castings may be made in green sand or dry sand molds.

The castings exhibit a dense pearlitic structure and a fine fracture. Piping is almost entirely absent.

6. Eutectic Cast Iron

When the various processes for the production of high-test gray cast iron are carefully analyzed, it becomes apparent that there must be some common denominator, some theory which fits all the cases. Very recently Mitinski published a paper in which he pointed out that from theoretical reasoning, eutectic cast iron should be sought in making stress-free, high-test gray iron castings. It is known that the carbon content of the eutectic alloy of iron and carbon is 4.3 per cent. This is decreased by the addition of silicon and other elements. For instance 1 per cent silicon reduces the eutectic composition to 3.88 per cent carbon, and 2 per cent further reduces it to 3.63 per cent. For 2 per cent silicon and 1 per cent phosphorus the eutectic contains 3.33 per cent carbon.

Osann, in a more recent paper, follows the same general idea and elaborates it. In the Lanz, Emmel and Krupp processes the pearlitic structure is obtained, but in the irons of higher silicon content, the graphite is not lamellar but granular. These irons are claimed not to grow under conditions of repeated heating and cooling, they do not pipe or shrink. Osann holds that the reason for the two latter properties is that the irons are eutectic alloys. Only

eutectic alloys have these properties, but other good properties are possessed as well, and they also preclude the formation of coarse, lamellar graphite.

Lanz, Krupp, Emmel, and Schüz irons are obtained by adjustment of the carbon and silicon contents. The same result may be brought about by superheating and the jolting of the liquid metal. Piwowarsky found that up to 2730 degrees Fahr. the graphite decreases and combined carbon is formed while the residual graphite is fine-grained. Hanemann tried to account for the facts by the germ theory of crystallization, but Osann does not accept this because of the doubt as to the origin of the nuclei. Sometimes superheating fails to achieve its purpose, and success seems impossible unless 30 per cent or more steel scrap is added to the melt. The same object can be attained, says Osann, without recourse to the expensive process of superheating, and in this connection he draws attention to the difference between kish graphite and solid solution graphite. By the latter is meant the graphite liberated by the dissociation of cementite in the solid state. It is the kish graphite which causes poor strength, wear, and frictional properties which must be present to satisfy the requirement of the high-test gray cast irons such as Lanz "Perlit," for instance.

The nuclei of Hanemann are essentially kish graphite crystals which persist during the operation of remelting. They may also be segregated phosphide eutectic or manganese sulphide. These concomitants are usually kept low in high-test cast iron. It is therefore necessary to see that kish graphite is not formed at the outset. It will then be unnecessary to superheat for the destruction of the nuclei. Attempts should be made to obtain eutectic graphite, and the composition of the cast iron should be regulated accordingly. The trouble starts with the pig iron which contains too much carbon in this day of frequent tapping and high hearth temperature.

According to Michel, in cast iron containing 2.8 per cent silicon, which solidifies with a gray fracture, or in others words, tends to the formation of graphite, kish graphite crystals separate

from the melt when the carbon content is greater than 3.1 per cent and these crystals are present during solidification. These graphite crystals give rise to faulty structure, either indirectly in the form of nuclei as indicated by Hanemann, or directly in the form of extraneous matter. With any cast iron containing 3.75 per cent carbon, there is present 3.75 minus 3.1 or 0.65 per cent carbon in the form of kish. With a different composition the eutectic point is displaced toward a lower carbon content. A number of practical cases are cited in which the kish was removed and the graphite content reduced, not by superheating, but by allowing the iron to stand and considerably retarding cooling.

It is not by mere chance that steel scrap in the cupola or in the electric furnace can be carburized up to a definite limit. The eutectic point is reached at 2.7 to 2.9 per cent carbon, and it is impossible to go further because the iron can dissolve no more carbon. In the ideal state, "Perlite" iron represents a eutectic alloy from which kish is excluded, and the same applies to other high-test irons as well. In Emmel iron the carbon is low in conformity with the increased percentage of silicon. The compositions of the eutectic cast iron alloys are not known. There is no single alloy, but a large number because each of the different silicon and phosphorus contents has its own eutectic carbon content. In order not to complicate the matter manganese and sulphur are assumed to remain constant. In this way there should be at least nine different diagrams.

Eutectic alloys do not pipe and this quality can be taken as a critical test of eutectic cast iron. Lanz and Emmel irons come into this category. All the various methods for the production of high-test gray cast iron meet at this point, and this is the common denominator which was sought. Consciously or unconsciously, all processes for the improvement of the properties of cast iron have been directed toward a eutectic composition because it has the advantage of the lowest melting point, it pours well because there are no free crystals in the molten mass, and the liquid solidifies without any auxiliary agency. A eutectic alloy therefore fills out the finest contours. After it has cooled this alloy exhibits

the best strength qualities and the best conditions of structure to withstand friction and wear because the molecules are able to arrange themselves undisturbed in the state of equilibrium. There is thus no possibility of segregation of piping and the shrinkage is at a minimum.

Piwowarsky advocated the superheating of iron and referred to the time factor. It may be that this result was not due so much to the superheating as to the elimination of kish graphite, and consequently the reduction of the carbon content. Superheating would simply shorten the time necessary. It would appear that the time-honored adage of "Melt hot and allow the iron to stand" has now been given a scientific foundation. In the Deschene process the separation of kish and sulphur is assisted by the fact that the iron is kept hot and in motion, and thus the desired result is brought about in a minimum time.

Conclusion

The methods of producing high-test gray cast iron are numerous and considerable differences among them are to be noted. The resulting castings have much the same structure and properties, which points to some underlying general theory as pointed out by Osann. The subject is still in a controversial stage, but it is quite evident that ways and means are now available for the production of better castings. Unfortunately the methods which have been proposed cannot be carried out without additional expense, but when it is considered that the quality of the product is made more uniform and certain, there should be no lack of interest on this account.

Science Hand in Hand with Labor¹

BY FRANK HUDSON,² KILMARNOCK, SCOTLAND

During the last few decades the foundry trade has witnessed a wonderful progress in knowledge, and many new discoveries. Practices which seemed impracticable to our forefathers have become standard to our business methods of today. The seemingly absurd suggestions of today will, no doubt, furnish the practical methods of tomorrow. What has been the success of this progress? Is it the thoughts of the scientist and metallurgist, or the work of the practical man? Surely neither can rightly claim the credit. The foundry trade can be likened to a monster machine supplied with power from *Capital*, constructed and driven by the cog-wheels of the *Practical Man*, and supplied with *Scientific* oil by the metallurgist.

All have a part to play, and it does not matter whether the machine is large and composed of many fast moving parts, representing the large and mechanized production foundries of

¹ This paper is one of a series on foundry problems being exchanged between the Institute of British Foundrymen and the American Foundrymen's Association. The first, prepared by the late George K. Elliott, was presented at the 1921 meeting of the Institute of British Foundrymen. The second was presented at the Rochester, New York, meeting of the American Foundrymen's Association by F. J. Cook, past president of the Institute of British Foundrymen. Professor Enrique Touceda presented the third paper before the British Society. The fourth was written by Dr. Percy Longmuir; the fifth by Major R. A. Bull; the sixth by Wesley Lambert and G. Hall; the seventh by Dr. R. J. Anderson and M. E. Boyd; the eighth by J. E. Fletcher; the ninth by Dr. H. Ries; the tenth by Arnold J. Lenz; the eleventh by John Shaw; the twelfth by Dr. J. H. Andrew; the thirteenth by J. T. MacKenzie; the fourteenth by F. A. Melmoth; the fifteenth by John Howe Hall, and this, the sixteenth paper, will be presented at the 1929 meeting of the A. F. A. on behalf of the I. B. F. The seventeenth will be presented at the June, 1929, meeting of the I. B. F. by J. W. Bolton in behalf of the A. F. A.

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Discussion of this paper begins on page 669.

today, or whether it is formed by the smaller and slow moving parts of the foundries of yesterday. Without *capital power* the works cease to revolve. Without *practical cog-wheels* the works come to a standstill. Without suitable *scientific oil* the machinery must be run at a lower speed. Furthermore, the right kind of *scientific oil* must be furnished to the *practical cog-wheels* to obtain the least friction with the fastest speeds.

For the continued progress of the industry, science must work hand in hand with labor, and it is the intention of this paper to bring forward in a practical manner those scientific applications of most benefit to the general foundry practice, which are apt to be overlooked by the practical man, and to create a discussion for the advancement of this question.

It is not the intention to treat with any patented improvement or process, but rather to select applications of international interest, which can readily be applied in almost any foundry. At the same time it should be understood that the scope of the paper is a large one, and if anyone considers that certain scientific applications have been omitted then the value of the discussion would be certainly improved by their mention. For convenience only those points relative to gray iron founding will be dealt with, especially applicable to foundries producing high duty castings, and castings subject to pressure.

The paper is divided into two parts, one section considering the helpful scientific applications that can be applied relative to the melting and composition of gray cast iron, while the other part treats with the molding and core-making side.

PART 1

Melting and Composition of Gray Cast Iron

The first essential for the successful production of gray iron castings is to decide upon the analysis of the iron mixture most suited to the castings being produced. This statement is not sufficiently appreciated by the practical man, who generally is only familiar with his two mixtures of hard and soft, special and common, or some such other terminology. These may mean anything. For example, his hard mixture, assuming it is semi-

steel, could easily range from 1.0 to 2.0 per cent silicon, or contain from 5 to 90 per cent of steel scrap.

The term semi-steel in itself covers a multitude of sins, and admits of little co-ordination, and there is an international need today for a term which will express or give some indication of the grade of semi-steel most suited for different classes of work. It has been suggested by the technical press of Britain that the term "steel-mix iron" would be preferable, giving the percentage of steel in the mixture as a prefix—for example, "20 per cent steel-mix iron," etc. This is certainly a suggestion worthy of further consideration as it will help to educate the practical foundryman into the ways of the metallurgist, and be the means of intelligently expressing scientific suggestions into practice.

Today many foundries have as many as six mixtures going through the cupola in one day's blow, and it can be safely said that the composition of the casting extensively determines its quality, freedom from defects, and future service. Considerable variation exists in the composition of the same type of castings from different foundries, according to the accepted views and technical knowledge on hand. In the author's own experience the composition specifications shown in Table 1 have always been accepted as a standard, and have proved their practical worth time and again, and are typical of the best practice.

Quality: The quality of gray iron castings is generally determined by their appearance as cast, and after machining, and by the test results of the inspector's bars. This question of quality representation by test bars has given rise to a great deal of thought in the last few years in order to try and correlate strength with mass effect, and so obtain a better idea of the actual strength obtainable in different sections of castings. This is a most important point to the designer.

The British Engineering Standards Association, in co-operation with the Cast Iron Research Association, has recently issued a new Specification,³ which is intended to further this matter, and suggests the use of round bars of varying sections according to the section of the casting being made. This is a

³ British Engineering Standard Association Report No. 321, 1928.

step in the right direction, but at the same time such a specification demands of the founder a more intimate knowledge of those technical points in the composition of cast iron which give quality, and good test figures. The specification shown in Table 1 has been drawn up with this fact in mind, and it has been found that cast iron, having the analysis as stated, will give the specified test figures. For example, a casting $\frac{1}{2}$ inch thick cast in dry sand with mixture No. 1 will give approximately 11 tons (24,750 pounds) per square inch tensile, while a large hydraulic cylinder 4 inches thick cast in No. 4 mixture will likewise give 11 tons per square inch tensile, these results being obtained from test bars of varying sizes to meet the difference in casting section.

Besides bearing upon quality, the composition of the iron has an important part to play in obtaining castings free from defects. In this connection the defect most troublesome to the average founder is that of shrink-holes. This is of particular import when castings are subject to a pressure test, and in this respect the specification shown in Table 1 has been instituted through research, and the composition of the irons shown therein found to exhibit the minimum of trouble to this cause.

Solidity: The solidity of gray iron castings is determined by several factors, such as metal composition, pouring temperature, method of molding, design, etc., and of these, composition has an important part to play. Especially is this the case when badly designed jobs are on hand, and it is peculiar that the more important castings, such as locomotive cylinders and valve bodies, etc., are the biggest offenders in this respect.

When a casting leaks under test, and the practical man has his suspicions of the presence of porosity and shrink-holes, he either thinks the metal is too hard, or else decides to put a riser on that spot, or some sort of feeding head. By softening the metal it is highly probable that matters are made worse, while by the inclusion of extra heads and risers up goes the weight of metal required for the job, and the ratio of castings produced to material melted is not so good, and all this helps to keep up high "oncost" or "overhead charges."

Iron with a suitable composition helps economic working. A concrete example came to the author's attention recently, as

Table 1
GRAY CAST IRON MIXTURE SPECIFICATIONS

TYPES OF CASTINGS

Ordinary Metal: For low and medium pressure castings made in green sand not over 1-inch section, low pressure castings in dry sand up to 1-inch section, structural work up to 1½ inches thick and general castings with no test specified.

Typical Applications: Pipes, light sluice valve bodies up to 24 inches, medium valve bodies up to 10 inches, heavy valve bodies up to 6 inches, extra heavy valve bodies up to 5 inches, general machinery castings, condenser and turbine castings, automobile cylinders, light and medium bed plates, etc.

Soft Semi-Steel: For low and medium pressure castings made in green sand between 1-inch to 1½-inch section, low and medium pressure castings made in dry sand up to 1½-inch section, heavy structural work and low pressure castings up to 2 inches thick.

Typical Applications: Heavy bed-plates or sole-plates, light sluice valve bodies above 24 inches, medium valve bodies above 10 inches, heavy valve bodies above 6 inches, extra heavy valve bodies above 5 inches, hydraulic pipes, low and intermediate marine engine cylinders, etc.

Semi-Steel for high pressure castings over 1½ inches thick.

Typical Applications: Hydraulic rams and cylinders not over 3-inch section, hydraulic valves, steam and pump cylinders, locomotive cylinders, high pressure valves over 2-inch section. Reciprocating or bearing engine parts in metal to metal contact. For cylinder work having unequal sections use mixture No. 3A.

Hard Semi-Steel for hard wearing castings, heat resisting work and exceptionally thick high pressure work.

Typical Applications: Hydraulic rams and cylinders over 3-inch wall thickness, heat resisting gas reversing valve tongues, ingot molds, bearing sleeves and races, castings for handling ammonia at high pressures.

Mixture No.	T. C.	Si.	ANALYSIS Mn.		P.	S.
I	3.5*	1.8 to 2.1	1		0.2 to 0.4	0.09†

Mixture No.	T. C.	Si.	ANALYSIS Mn.		P.	S.
II	3.3*	1.5 to 1.8	1		0.2 to 0.4	0.09†

Mixture No.	T. C.	Si.	ANALYSIS Mn.		P.	S.
III	3*	1 to 1.2	1		0.2†	0.10†
III A	3.5*	1 to 1.2	1		0.2†	0.10†

Mixture No.	T. C.	Si.	ANALYSIS Mn.		P.	S.
IV	3*	0.6 to 1	1		0.2†	0.10†

*Approx.

†Max.

NOTE: If castings are authorized to be cast with metal other than stated here raise a query.

shown in Fig. 1, which shows a 2 inch hydraulic stop valve body for 2,500 pounds per square inch test pressure. Valve A was the general method used for molding, employing a large feeding head and casting vertical with soft iron, of the composition: T.C. 3.30 per cent, Si. 2.00 per cent, Mn. 0.70 per cent, P. 0.60 per cent, and S. 0.075 per cent.

Without the feeding head trouble invariably occurred due to leakage on test. By altering the composition to a semi-steel mixture similar to mixture No. 2 in Table 1, and casting on the side as shown at B, Fig. 1, it was found that the head could be dispensed with, and the resulting casting was perfectly tight on test, and possessed a very much superior appearance after machining. This enabled a large saving to be made in machining time, while the removal of the head, which was 95.7 per cent of the weight of the casting, resulted in a saving of metal, and increased production.

In Fig. 2 is illustrated a similar saving on a larger casting through the use of correct composition. Another example came to light in the casting of locomotive cylinders. These cylinders were a constant source of trouble due to leakage under test in the piston valve steam ports. The cause was unquestionably due to porosity, and the presence of shrink-holes through unequal sectional metal. The obvious practical solution was the use of chills or denseners, and at one time numerous chills were in use on a single cylinder. This certainly improved matters, but did not entirely cure. The average composition in use was T.C. 3.3 per cent, Si. 1.2 per cent, Mn. 0.70 per cent, P. 0.42 per cent, and S. 0.08 per cent. This was modified to T.C. 3.53 per cent, Si. 1.0 per cent, Mn. 1.0 per cent, P. 0.12 per cent, and S. 0.08 per cent, and sound cylinders were obtained without the use of a single chill. It will be noticed that particular mention is made of this iron in Table 1, as mixture No. 3A. The average hardness of this composition runs around 212 Brinell and 18 tons (40,500 pounds) per square inch tensile was regularly obtained.

These are not isolated cases of individual experience, but other instances can be cited, selected from the various technical proceedings and transactions. For instance, Smalley⁴ gives ex-

⁴ O. Smalley, *Proc. Inst. of Brit. Foundrymen*, 1922-23, p. 432.

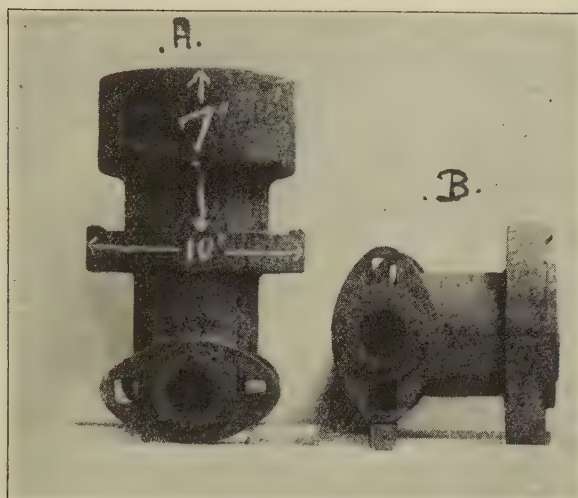


FIG. 1—EXAMPLE OF CHANGED MOLDING PRACTICE—A, MOLDED ON END (OLD WAY) WITH HEAD; B, MOLDED ON SIDE (NEW WAY) WITHOUT HEAD

	Cwts.	Qtrs.	Lbs.
Weight of casting.....	0	2	14
Weight of head	0	2	11

Head 95.7 per cent weight of casting

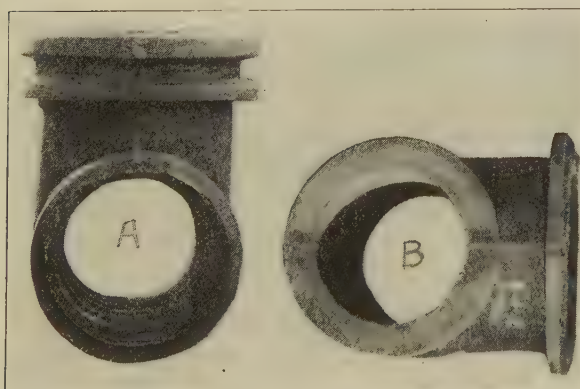


FIG. 2—EXAMPLE OF CHANGED MOLDING PRACTICE—A, MOLDED ON END (OLD WAY) WITH HEAD; B, MOLDED ON SIDE (NEW WAY) WITHOUT HEAD

	Cwts.	Qtrs.	Lbs.
Weight of Casting.....	4	1	2
Weight of Head	1	0	0

Head 23.4 per cent weight of casting

amples of obtaining greater solidity in sluice valves, and the displacement of chills on unequaled sectioned metal at the valve faces, by a revision of composition. The reason for obtaining sounder castings by the use of correctly compositioned mixtures is explained by the work of Smalley, MacKenzie, Bolton,⁵ and others, and it is very desirable that their writings upon this subject should receive greater attention. In fact, an extensive practical application of such work would do far more good to the general foundry trade than many other scientific researches published in the last few years.

The references cited in this paper should be studied by all interested in this question, as the information is such as to be quite understandable by the bulk of practical workers. However, it can be stated that all shrink-holes and porosity are formed during the freezing or setting period of the molten iron in the casting, and the composition determines the length of this period. The softer the iron, the greater the freezing period, and the harder the iron becomes then the less is the freezing period. It is obvious that the smaller this range, the likelihood of porous castings being produced is correspondingly reduced. Of course, it should be clearly understood that casting temperature, type of mold used, molding methods, and cupola operation are all bound together for success in this matter, and these will receive consideration later.

By reducing the total carbon, silicon, phosphorus and manganese, and by increasing the sulphur, an iron with the lowest freezing period is obtained. This, however, would not be good practice used indiscriminately, as trouble would certainly arise due to lack of fluidity, and hard castings produced. The bulk of

⁵ *Cast Iron and Its Chemical Composition*, O. Smalley, Proc. Inst. of Brit. Foundrymen, 1921-22, p. 688.

Volume Changes of Cast Iron on Solidification, O. Smalley, Proc. Inst. of Brit. Foundrymen, 1922-23, p. 405.

Some Notes on Liquid Contraction, R. Buchanan, Proc. Inst. of Brit. Foundrymen, 1922-23, p. 571.

The Cylinder Problem, O. Smalley, Proc. Inst. of Brit. Foundrymen, 1923-24, p. 491.

Phosphorus Affects Qualities of Gray Cast Iron, J. W. Bolton, "The Foundry," May 15, 1926, p. 378, and June 1, 1926, p. 423.

The Influence of Phosphorus on the Total Carbon Content of Cast Iron, J. T. MacKenzie, Trans. Am. Foundrymen's Assn., Vol. XXXIII, p. 445.

The Influence of Phosphorus on Cast Iron, J. T. MacKenzie, Trans. Am. Foundrymen's Assn., Vol. XXXIV, p. 986.

the information on hand relative to this question suggests that the manganese and sulphur should be constant around 1.0 per cent Mn, with the sulphur not exceeding 0.10 per cent, and the necessary variations made in the other elements. In the author's experience it has been found that for high class work the total carbon content should not drop below 3.0 per cent and for cylinder work, having variation in section, an increased amount of total carbon up to 3.5 per cent is desirable.

The present-day tendency for total carbon contents below 3.0 per cent is not essential for general foundry practice, and leads to difficulties. The important part the total carbon plays in the solidity of castings is unquestionably hinged upon the cooling rate and casting section. With the same cooling rate and casting section an increase in the total carbon content brings about "liquid expansion," which in conjunction with a composition of short freezing range is an invaluable help for obtaining solid castings having varying section in their design. However, the use of high total carbon mixtures and the consequent increase in graphitic carbon demands that low phosphorus contents be used to obtain satisfactory toughness and good test results.

Fluidity: The fluidities of the compositions shown in Table 1 are perfectly satisfactory, providing they are used for the sections stated, and consistent with good cupola practice. It is thus obvious that in drawing up this table an attempt has been made to correlate composition with casting quality as determined by strength and solidity, in order to provide a suitable working basis for the foundryman. At the same time, it is quite probable that the grade of material used to obtain the mixture such as quality of pig iron, percentage of scrap, etc., will cause different results to be obtained even in cast iron of similar analysis. This point will be considered under the next paragraph on the melting of gray cast iron.

Melting of Gray Cast Iron

Unless careful and consistent cupola operation is practiced, the values accruing from composition specifications are negligible. The melting of cast iron has been very badly neglected in the

past, and very little real general practical progress has been made. New developments, from time to time, have been brought out which tend to perfect the working of the cupola. These should be very carefully considered before adoption, as a great number are old facts in disguise, and the foundryman could have easily applied them himself if he had tried to study the working and changes taking place within the furnace. Other improvements, however, are well worth installing.

The cupola, as a furnace which nowadays has to be controlled to give definite results, is certainly a difficult proposition, yet when run under scientific lines gives wonderful uniformity for general foundry practice. Cupolas are too often left to be managed by men, who through lack of sufficient knowledge, dare not deviate from their present practice. The essentials to be looked for in good cupola practice may be stated as follows:

- 1.—Careful weighing of all pig iron, coke, etc., including air.
- 2.—Careful analysis in conjunction with physical tests of all raw materials used.
- 3.—Correct fluxing.
- 4.—Rapid and hot melting. The molten iron should leave the furnace spout having a temperature of at least 1400 degrees Cent. (2500 degrees Fahr.). The hotter the better.
- 5.—The brickwork at the charging door should never exceed black or dull red heat until the last 30 minutes of blow.
- 6.—Correct flame at the charging door. A bluish-pink flame, clinging to every little projection and ledge in the chimney stack, now and again running down and burning at an opening in the charges.

Mechanical charging is equally as good as hand charging, and saves the double handling necessary for hand charged cupolas after the weighing operation.

The system in use by the author is shown in Fig. 3 and has proved perfectly satisfactory.

Blast control is a vital factor, and it is essential for successful control. Fig. 4 illustrates a typical pressure and volume meter, and the limit marks on the volume indicating tube should



FIG. 3—CUPOLA CHARGING ARRANGEMENT

be particularly noted. These are set by the laboratory, according to the best practice, and the cupola controlled by the furnaceman to give a constant figure. Constant blast pressure and volume is most important in cupola working, as this is the absolute index of a constant melting zone. In this respect another point which is often lost sight of is that the melting zone is fixed by the tendency of the air to travel upwards. Any disturbing factor, such as a large open slag-hole, will lower the melting zone, and possibly give dull metal. The slag-hole in cupola working should only be opened when absolutely essential, and then closed as soon as possible, or on the other hand, kept open altogether.

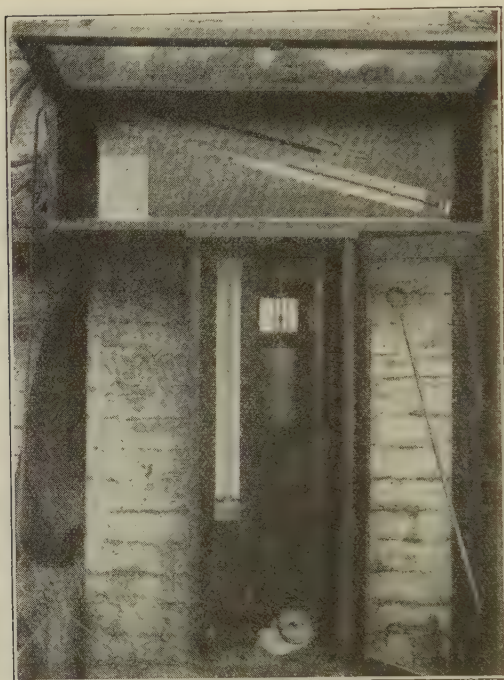


FIG. 4—CUPOLA BLAST CONTROL INSTRUMENTS

Some years ago the author conducted a research⁶ upon the melting and casting of high duty irons, and an investigation into the changes taking place inside the cupola, and obtained the conclusions that three distinct zones existed in which the following changes occurred:

Zone 1.—Extending from the charging door sill down to beginning of melting zone. For practical purposes cast iron and steel mixtures in this zone absorb no extra carbon until actual melting begins.

Zone 2.—The actual melting zone. Cast iron and steel melt just above the hottest zone at their respective melting temperatures, and fall through the hottest zone in small drops,

⁶ *The Melting and Casting of High Duty Irons*, F. Hudson, Proc. Inst. of Brit. Foundrymen, 1924-25, p. 401.

this zone having a temperature of at least 1650 degrees Cent. (2940 degrees Fahr.), which is amply sufficient to superheat these small drops. Carbon absorption now takes place very rapidly, due to high temperature, and intimate contact with incandescent coke.

The degree of carbon absorption depends upon the prevailing atmosphere in the melting zone, and the composition of the material being melted, together with time and temperature in the melting zone. The higher the temperature the more the carbon will tend to be absorbed in a certain time, according to the facility of applying free carbon and the re-activity of the coke structure. The absorption is lowered by excessive blast with the consequent production of an oxidizing atmosphere, and material containing a low carbon content such as wrought iron or steel will probably not pick up as much carbon as cast iron. All cast iron material is superheated in the true sense of the term superheat, while wrought iron and steel are not superheated in the true sense of the word, but by melting at a high temperature and solidifying at a much lower temperature obtain a superheat greater than the cast iron material.

Zone 3.—Extending from the melting zone to the well. The molten metal lying in the hearth or well falls in temperature, and in the case of cast iron material probably loses carbon. Steel charges may, however, still absorb further carbon, according to the degree of carbon absorption obtained when passing through the melting zone. Sulphur is absorbed in the last two zones.

Total Carbon Control

At the present time total carbon control in the iron foundry is a very difficult matter, and likely to become of extreme future importance in the development of high test material either through the use of alloy additions or by modified melting practice. The original carbon content of the material being melted has very little bearing upon the final carbon content after melting, and it can unquestionably be stated that cupola control is the key to this matter.

For general high duty castings using varying quantities of steel in the mixture, and giving a minimum of 3.0 per cent total carbon after melting, the aim should be to have the correct amount of air to combine with the coke to give a neutral or very slightly oxidizing atmosphere. The lower the blast pressure, consistent with correct volume, the hotter is the metal obtained, due to a lower melting zone and hotter hearth.

High total carbon irons melt hot, but slowly. The melting point of the materials used has quite an appreciable effect upon the resulting temperature obtained, and in the author's opinion this point has quite a bearing upon the preference for sand cast instead of machine cast pig. It is suggested that the combined carbon figure determines the actual melting point.

In conjunction with the need of cupola control for obtaining the correct total carbon contents, the important part played by the coke must not be forgotten. MacKenzie⁷ has shown that different degrees of carburization can be obtained according to the structure, and physical properties exhibited by the coke used for melting, and this is further accentuated in the Corsalli process used for obtaining high test cast irons where the re-activity of the coke is diminished by immersion in a lime sludge, and an oxidizing atmosphere obtained during melting by increased blast. This produces extremely low total carbons.

Important Cupola Operation Factors

In the melting of cast iron to be used for quality castings the following points should be remembered:

- 1.—The bed coke should be measured by volume, and the charged coke by weight.
- 2.—The metal mixture should be of uniform size. Too small and thin bulky material produces oxidized metal, while large thick sections produce cold metal.
- 3.—Every care should be taken to keep a constant melting zone, influenced by the presence and volume of blast used.
- 4.—Proper fluxing, using a slightly basic slag, together with hot melting, will keep the sulphur low. (This can be obtained by

⁷*The Properties of Coke Affecting the Cupola Melting of Steel*, J. T. MacKenzie, Proc. Inst. of Brit. Foundrymen, 1926-27, p. 46.

the use of a small amount of manganese ore with the limestone.)

5.—Careful attention to the small points.

6.—Hot melting is essential for good work.

Suitable Mixtures

This section would not be complete without reference to the suitability of different mixtures, and brands of pig iron for gray iron castings.

The author prefers to use a synthetic cold blast iron, containing at least 10 per cent steel scrap, made in a cupola or open-hearth furnace. This is remelted with siliceous hematite (5 per cent Si.) and a slight percentage of steel and domestic scrap added for cylinder work. In all pressure castings with variation in section, over 15 per cent of steel scrap is never added directly to the mixture without remelting, although the final mixture may actually contain well over 50 per cent steel scrap in the remelted condition. This is usually done to obtain a total carbon content of approximately 3.5 per cent as low total carbon iron is not recommended for work other than perfectly uniform sections.

Table 2 illustrates a specimen daily cupola record showing the control that should always be the practice in progressive foundries. In the author's own works this system has resulted in a saving of between 2 to 3 per cent in defective work.

Pouring Practice

All high duty work should be poured hot. Pouring hot is essential, whether the casting be large or small, thick or thin, if the best work is to be turned out. Lack of density in castings is due to casting at too low a temperature. This lack of density is due to either blow or shrink holes.

In large castings foundrymen as a rule have often a certain fear of casting hot. That this is a fallacy was brought home in the author's experience some time ago. A Diesel engine flywheel, of about 12 tons weight and 36-inch section, had been cast on the cold side and was badly drawn under the risers. Prior to this, one had been cast very successfully at a higher temperature. The

first wheel had taken about 6 or 7 hours to feed, while the second had only taken about 5 hours. Obviously the faulty wheel had taken less metal, and had a lower density, and if it had been cast hotter, the casting would have been sound. Fig. 5 illustrates the uniformity or hardness through a 3 inch thick section at $\frac{1}{4}$ inch spaces from edge to center when cast hot and cold. The uniformity unquestionably lies with the hot cast section.

Fig. 6 shows the above sections when fractured, and the blow holes shown in the cold cast section are generally, for semi-steel at any rate, a sure sign that the metal has been cast cold. The casting temperature for general cylinder and high duty work should be between 1350 to 1400 degrees Cent. (2400 to 2490 degrees Fahr.).

PART 2

Molds and Cores

It has often been said that the greater proportion of defective castings can be attributed to bad cupola practice rather than to the actual casting and making of molds and cores. Such a statement is open to very grave doubts, as an unbiased consideration suggests that the greater number of defective castings produced in most foundries is due to poor and badly supervised pouring and molding operations. At any rate, this department calls for probably more of the "human element" than any other foundry operation, and consequently is open to mistakes and miscalculations. However, in the last few years the foundryman has had placed at his disposal definite means of controlling several of these variables. Increased adoption of machine molding, systematic study of sand preparation and handling equipment, efficient drying stoves, and sand and core testing, and control apparatus, have helped enormously to minimize rule of thumb methods, and it behooves the practical man to take advantage of these benefits for his own good progress.

The testing of foundry sands and molds is yet in its infancy, and every credit is due to the American Foundrymen's Association for its work in this direction.

Foundry Sand, Mold and Core Control

Ideal sands exist for every foundry, according to the method of molding, and the class of castings being made. The ideal, however, can never be reached by chance and only becomes apparent by those who make an attempt to study and test molding and core sands. The apparatus adopted by the American Foun-

Table 2

DAILY CUPOLA REPORT.

GLENFIELD & KENNEDY LIMITED, KILMARNOCK.

Date 21 Aug. 28 Blast on 10.30 A.M. Bottom Dropped 5.0 P.M.
Cupola No. A.

No. of CHARGES	MIXTURE					CAL. ANALYSIS		ACTUAL ANALYSIS					Wt. of CHARGE		Wt. of CORE		Wt. of LINT.		BLAST		REMARKS.
	MATERIAL	Tons	Cwt.	Qrs	Lbs	Si.	P.	Tc.	Si.	Mn.	P.	S.	Cwt.	Lbs	Lbs	Press	Vol				
<u>1</u>	SCRAP	-	15	-	-	2.2	40						30	334	100	18"			Run off metal		
1	HEMATITE	-	7	2	-														Mixture No.1		
	SCOTCH No.3	-	7	2	-	2.0	40						"	"	"	"					
	SCRAP	-	15	-	-																
<u>6 1/2</u>	HEMATITE	-	7	-	-														Mixture No.2.		
	SCOTCH No.4	-	8	-	-	1.5	30						"	"	"	10"					
	STEEL	-	7	-	-																
	SEMI-STEEL SCRAP	-	8	-	-																
30	HEMATITE	-	7	2	-			2.02	85	21	073					10"			Mixture No.1		
	SCOTCH No.3	-	7	2	-	2.0	40	2.02	80	29	079		"	"	"	Tc					
	SCRAP	-	15	-	-			2.06	82	25	069					14"					
								1.97	77	45	073										
	KEEP 8 SHRINKAGE TEST = .142" Per foot.																				
	TRANSVERSE TEST 1" x 2" bar on 3ft. centres = 31 Cwt.0 Qrs. 8 Lbs. with .529" defl.																				
	MATERIAL ANALYSIS.																				
	HEMATITE					4.02	21	4.05	06												
	SCOTCH No.3					3.42	41	0.50	06												
	SCOTCH No.4					3.51	71	2.50	06												
	SCRAP					3.32	0.90	4.00	08												

MELTING RATE 9.1 TONS PER HOUR.
TEMPERATURE AT CUPOLA SPOUT = 1400 °C (OPTICAL).

Weight of Bed Coke 1-2-3-0
Total Iron Melted 57-0-0-0
Total Coke Used 5-13-1-8
Total Limestone Used 1-13-3-20
Coke Ratio to Iron Melted 1:10.0

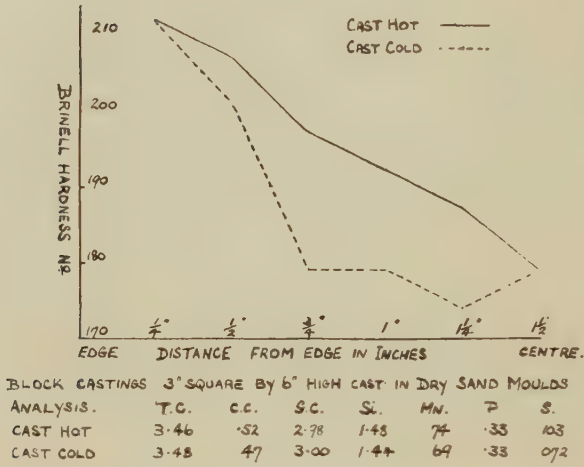


FIG. 5—HARDNESS READINGS FROM EDGE TO CENTER OF BLOCK CASTINGS WHEN CAST HOT AND COLD



FIG. 6—FRACTURE OF BLOCK CASTINGS WHOSE HARDNESS READINGS ARE SHOWN IN FIG. 5

drymen's Association, or that developed by the author,⁸ have been devised essentially to help the practical man, and by their use it is possible to gauge the true value of foundry sands and guarantee successful casting production. On the other hand, sand testing and control paves the way to the elimination of defective molds, and gives a means for correction. Figs. 7a to 7f illustrate the practical foundry mold and core testing apparatus in use in the author's foundry.

A. Mold Hardness Tester

The mold hardness tester (Fig. 7a) consists of a brass base-plate supporting a bearing in which slides a plunger. At the top of this plunger is a loading table, while at the bottom is embedded a $\frac{3}{4}$ inch diameter steel ball. Surrounding the bearing is an ebonite ring having copper contact points at the top, this serving both as a distance stop for the ball penetration, and also for coupling up with a small electric lamp and battery as an indicator when maximum ball penetration has been obtained. The principle of the test is to apply weights to the table until contact is made on the ebonite ring when the lamp lights. At full load the ball is embedded in the mold up to half its diameter, namely, $\frac{3}{8}$ inch. The hardness index of the mold under test is expressed by the weight required to embed the ball plus 2 pounds, which is the weight of the table and plunger. The use of this instrument gives an index of the amount of ramming applied and the variations existing in molds and cores due to that ramming.

B. Green Dropping Test Sampling Tube

This consists of a brass tube having a knife edge at one extremity, and a cap at the other, having a slow thread screwed hole, in which works a long spindle attached to a piston. The cross-sectional area of this tube is exactly 1 square inch. The method of using this tube consists in screwing back the piston to the closed end and pressing the open end into the mold, and extracting a sand sample similarly to cutting runner and riser "gits" as practiced by the molder. Upon ejecting the sand in a

⁸ *Scottish Molding Sands*, F. Hudson, Foundry Trade Journal, April 12, 1928, p. 262, and April 19, 1928, p. 279.

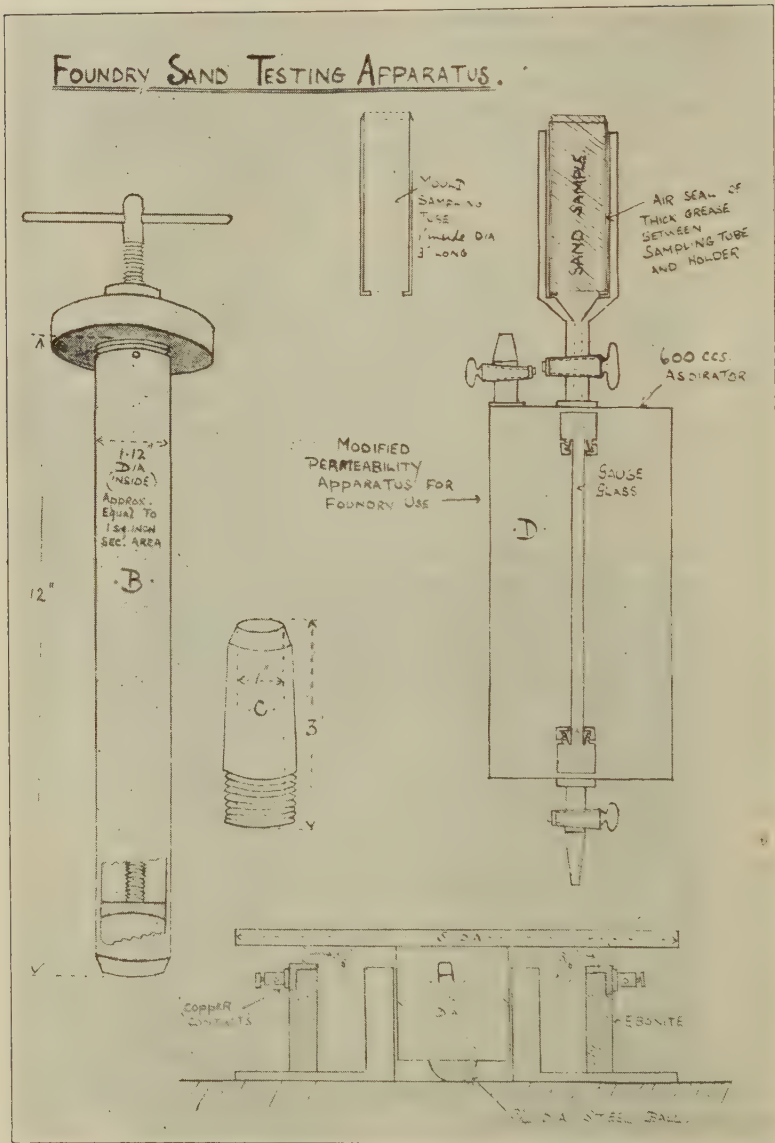


FIG. 7a—FOUNDRY SAND TESTING APPARATUS

horizontal plane by means of the piston and measuring the "overhang" after fracture of the sand has taken place, an index of the bond strength is obtained.

C. Mold Permeability Apparatus

In this test the small sampling tubes illustrated are pushed into the mold similarly to tube B, described above, and placed into the aspirator which draws a standard volume of air through the sand under test. This apparatus consists of a cylindrical aspirator vessel connected to a brass test-piece holder. A complete operation for testing a green sand mold is as follows:

The permeability sampling tube is greased inside and pressed into the mold. After extracting, the ends are leveled and the outside of the tube cleaned and coated with grease. (Grease is used for obtaining air-tight connection.) The cock at the base of the aspirating vessel is now closed and the two top ones opened. Water is poured into the holder until the vessel is full as shown

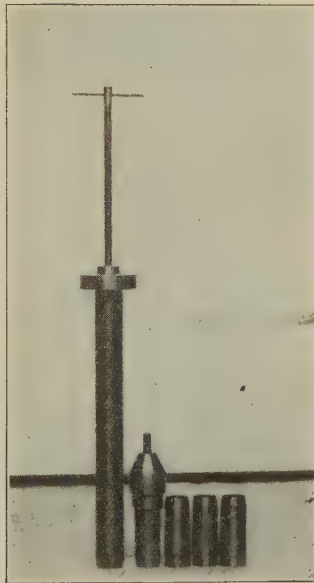


FIG. 7b—GREEN DROPPING SAMPLING TUBE

by the water gauge. Both these cocks are now closed, and the bottom cock opened. The sampling tube is now placed inside the holder and the cock at the base of holder (X) opened, when the water escapes and air drawn through the sand sample, the time in seconds taken for the water to drop from the top of the water gauge glass to the bottom being an index of the permeability of the sand. For dry sand samples the mold is sampled in a similar way when green, and the mold and sample dried together. After drying, the sand sample is extracted from the tube, and the inside of tube coated with thick grease, and the sample replaced and the test completed as described above.

D. Moisture Meter

This is a modification of the electric resistance method, and is based upon the principle of measuring the electric current passing through damp molding sand, the intensity of the current varying according to the amount of moisture present. The as-

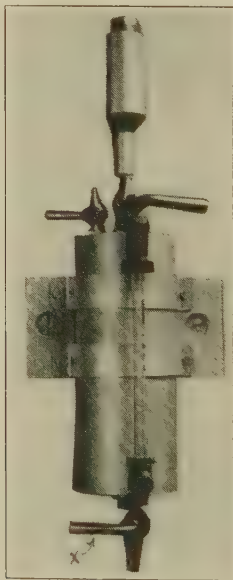


FIG. 7c—MOLD PERMEABILITY APPARATUS

sembly consists of a galvanometer battery and resistance board. This latter consists of a mold 6 inches by 2 inches square, containing 2 cupro-nickel electrodes 5 inches apart. Attached to the board is a jolt-ramming device. This is to ensure uniform packing conditions of the sand in the mold. The method of using is to pass the sand sample through an $\frac{1}{8}$ inch riddle, and then fill the mold box without any ramming to the sand whatsoever. After leveling the top, the box is given 30 jolts, and the deflection of the galvanometer noted, which is an indication of the moisture content. It is important to note, however, that every different type of sand must be standardized on this instrument against a chemically conducted determination.

A very interesting point came to light in experiments on this apparatus. It was noted that when a dried sample was tempered with water, the galvanometer deflection was much greater on a freshly tempered sample than on the same sand sample after standing several hours with a uniform moisture content. This would appear to have some bearing upon the fact that most molding sands exhibit superior physical properties after being allowed to stand after tempering, the reason probably being due to the fact that the clay or other colloidal bond around the sand grains does not develop its correct bonding power until a certain time has elapsed, and the added water has had time to uniformly penetrate the bond coating. At the same time it is quite probable that testing molding sands for electrical resistance will give a good indication of their heat conductivity.

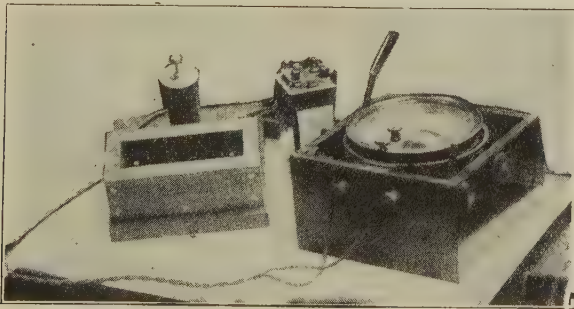


FIG. 7d—MOISTURE METER WITH RESISTANCE BOAT



FIG. 7c—MOISTURE METER ON JOLT RAMMED TEST MOLD

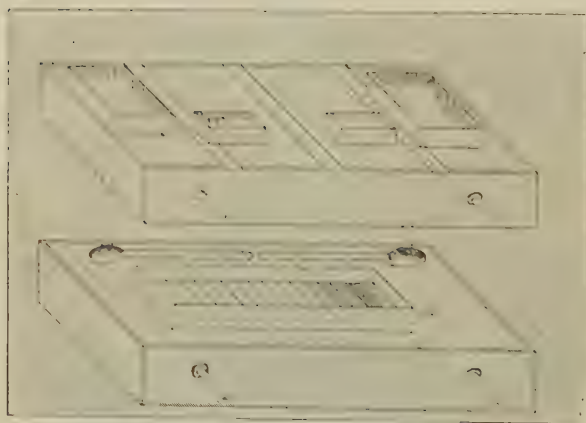


FIG. 7f—TEXTURE AND REFRACTORINESS TEST MOLD

E. Texture and Refractoriness Test

A mold is made as shown when the experimental sands are made up into 2 inch wide blocks to form the base. The mold is cast with hot iron, and from the resulting casting, the refractoriness of the sands can be gauged according to the amount of sand fritting which has taken place, and the skin producing powers readily shown after sand blasting.

By testing the molds as described, and following the resulting castings through the final stages of manufacture in the dressing and machine shops, it is not a difficult matter to draw up the necessary properties required of a mold and cores for successful casting production. For example, the specifications of Table 3 have been obtained for brass and gray iron castings.

Table 3

GREEN SAND MOLD SPECIFICATIONS (Hand Rammed)

BRASS AND GUNMETAL CASTINGS (i.e., stop cocks, sluice valves, valve seat rings, sluice faces, hydrants, etc.).

Mixture	Parts	Moisture Content, per cent	Mold Hardness, pounds	Bond Strength, inches	Permeability seconds
Belfast Red Sand....	100	7	16-18	1.5	120

GRAY IRON CASTINGS (i.e., small sluice valves, standposts, handwheels, water meters, sluice frames, etc.).

Mixture	Parts	Moisture Content, per cent	Mold Hardness, pounds	Bond Strength, inches	Permeability seconds
Floor Sand	8	7	19-22	1.8	80
Drumcavil Rock Sand.	4	7	19-22	1.8	80
Wormit Red Sand....	3	7	19-22	1.8	80
Coal Dust	1	7	19-22	1.8	80

Molds having these physical properties will produce satisfactory castings in the hands of skilled molders, although it should be pointed out that in this specification it would be advantageous to increase the bond strength in order to prevent scabbing and cutting when the sand is worked by unskilled labor.

However, it is essential to have some such specification as this, based on actual practical results, for a starting basis in order to obtain mold and sand control, keeping the facts in mind that consistent with the necessary sand texture the higher the bond strength and the greater degree of permeability, the more fool

proof becomes the sand for practical application. An ideal sand should have the following characteristics:

Spherical one sized silica grains.

Spherical grains to give permeability.

A predominating grain size.

Fine for finish, coarse for refractoriness.

Sufficient bond.

Just sufficient bond coating each spherical grain to give the necessary strength without impairing the continuity of the pore spaces.

A careful consideration of these points by the practical man, and by the use of sand testing equipment, will supply material for rapid progress, better and cheaper castings, and greater efficiency. Knowledge of the following points, in definite figures which can be immediately applied to practical application become available:

- 1.—The effect of sand preparation machines.
- 2.—The most suitable sand mixture for casting production.
- 3.—The most economical sand can be obtained.
- 4.—Sand mixtures to increase production. (For instance, self-venting sands.)
- 5.—Reclamation of old sand.
- 6.—Effect of the different molding methods. (Machine versus hand.)
- 7.—Elimination of defective castings from mold defects.
- 8.—A working knowledge of the relative values of each molding sand.

Surely these advantages give more than ample reason for the universal immediate progress of sand testing, and greater intimate co-operation between science and practice.

Cores

The adoption of oil sand cores to foundry practice is one of the biggest benefits to the practical man in recent years, and it is surprising how many foundries do not avail themselves of the

benefits arising from their use. The advantages obtainable over dry sand cores can be stated as follows:

- 1.—Strength and permeability unaffected by variations in ramming.
- 2.—Freedom from scabbing and causing blow-holes.
- 3.—Increased production in fettling.
- 4.—Lower drying time with decreased coke consumption.
- 5.—Increased production.
- 6.—Ease of mixing.
- 7.—Little volume change after drying.
- 8.—Good skin produced on casting without use of blacking.
- 9.—Saving in core irons.
- 10.—Easily handled after drying.
- 11.—Promotes softer skin on casting and lowers machining difficulties.

Here again, however, the full benefits of oil sand core practice can only be obtained by co-operation between science and the practical man. For instance, the number of core-oils offered to the foundry trade today demands that all should be tested in regard to strength against quantity required, and consequent cost of mixture. Different oils require variations in drying schedules and impart entirely different characteristics to the sand mixture when green. For instance, cores which require to be made in halves when using a plain linseed-oil sea-sand mixture could be made in one piece by the use of a different oil or by the inclusion of a bonded sand. It would seem, however, that much of the simplicity of oil sand is lost by the inclusion of a bonded sand as the mixture becomes more susceptible to ramming effects, has less permeability, and requires more oil for a given strength. A very great deal of valuable practical information can be obtained by using a modification⁹ of the sand testing apparatus for testing oil sand core compositions. In this respect the suggested test methods would consist of tensile, transverse and permeability

⁹ Scottish Molding Sands, F. Hudson, Foundry Trade Journal, April 12 and 19, 1928.

tests conducted on dried samples together with a green dropping test to give an index of the bond strength before drying.

Tensile: For this purpose use was made of the standard cement mold having exactly 1 square inch section across the neck, the resulting test piece being fitted with the necessary grips so that it could be broken by weighting or by the use of a cement tensile testing machine.

Transverse: This consisted of a suitable core box to produce a test piece 6 inches long by 1 inch square, which was broken by suspending a load from mid-center from a $\frac{1}{4}$ inch round shackle, the breaking center being 4 inches apart.

Permeability: Conducted as previously described.

Green Dropping Test: The sand is rammed up in a skeleton core box on a $\frac{3}{8}$ inch thick glass plate to give a bar of sand 12 inches long by 1 inch by 1 inch. The glass plate projects over the edge of a bench, and the sand is gently pushed over the edge of the plate until the sand collapses. The length remaining (measured from the middle of the fracture), subtracted from the original length is recorded as a measure of the bond, the average of at least 4 tests being taken.

All test pieces are dried at 350 degrees Fahr. and a standard silica sand used for mixing. Little trouble is experienced from

Table 4
STANDARD SAND SIEVE TEST
(Irvine Sea Sand)

Mesh No.	20	30	40	60	80	90	100	120
Per cent passing...	96.59	94.01	90.97	77.85	26.89	14.42	9.85	1.72

STRENGTH AND PERMEABILITY TESTS

Mixture	Green Drop- ping Test, inches	Tensile Strength, ozs. per sq. in.	Transverse Strength, ozs. per sq. in.	Perme- ability, seconds
Sea Sand.				
2% boiled linseed oil (Baltic)...	1.1	1921	442	51
Sea Sand.				
2% boiled linseed oil.....	..	1541	732	50
Sea Sand.				
4% boiled linseed oil.....	..	4780	1918	48
Sea Sand.				
1% boiled linseed oil.....	..	4502	1248	52
Sea Sand.				
1% boiled linseed oil.....	..	255	105	40
Sea Sand.				
2% pale boiled linseed oil.....	..	11	4	40
Sea Sand.				
2% boiled linseed oil.....	..	414	130	46
Sea Sand, 40 lbs.				
Semi-solid core-compound, 2 lbs.	2.5	2722	805	57

All samples baked at 350 degrees Fahrenheit, except green dropping test, which is tested green.

ramming variations due to the nature of these mixtures, and very concordant test figures are easily obtained.

Table 4 gives an example of the application of such tests to oil sand compositions. A matter of particular note is the large variations in core strength due to differences in quality of the linseed oil, and the value of these tests for controlling core oil quality is very obvious. Pure linseed oil is derived from the seeds of the flax plant, and it is peculiar that the colder the climate in which the flax plant grows the better the oil seed. As a result the best oil comes from the Baltic, and the worst from India. From these tests it is also interesting to note that mixtures can readily be produced that will give considerable bond in the green condition which is often of considerable help for certain classes of cores. Within recent years core oils have been added to loam jobs, and as a result less cracking of the mold surface is apparent after drying, and consequent less risk of defective castings.

Loam Mixtures Containing Core Oil

Some years ago the author did some work in this direction, and a mixture found very suitable was as follows:

Milled in light pug-mill

- 2 large shovels sea sand.
- $\frac{1}{2}$ large shovel floor sand.
- $\frac{1}{2}$ large shovel Erith loam.
- $\frac{1}{4}$ large shovel cow hair.
- 2 pail-fulls linseed oil compound.

The oil compound consisted of 1 part water, 1 part boiled linseed oil, and a very small quantity of ammonia to promote saponification. This was milled for 10 minutes, and watered to the correct consistency when the following results were obtained on the sand testing apparatus:

Dried at 350 degrees Fahr. for 6 hours

- Transverse, 1,524 ounces per square inch.
- Permeability, 992 seconds.

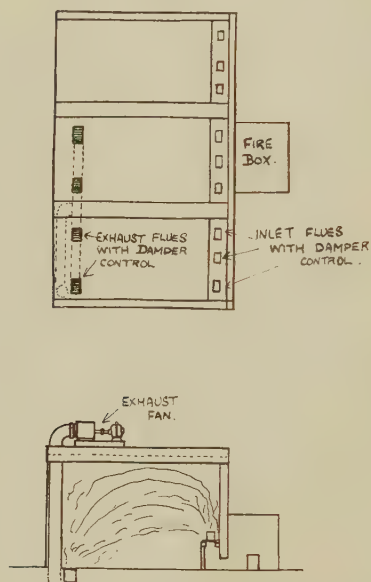


FIG. 8—LAYOUT OF CORE DRYING OVEN



FIG. 9—OUTSIDE VIEW OF CORE OVEN

For comparison with the above figures, the following was representative of ordinary stiff fine loam:

Dried at 450 degrees Fahr. for 4 hours

Transverse, 511 ounces per square inch.

Permeability, 1,230 seconds.

The advantages of the oil addition was an increase of nearly 300 per cent in strength, better permeability to the extent of approximately 20 per cent, and freedom from drying cracks.

It would appear that the full knowledge and advantages of core oil use for foundry service has as yet only been touched upon, and the future will see wonderful progress in this direction. The reclamation of old cores and burnt core sand is another important matter. The burnt material makes an ideal parting sand, and can be used to open up green sand molds by incorporation

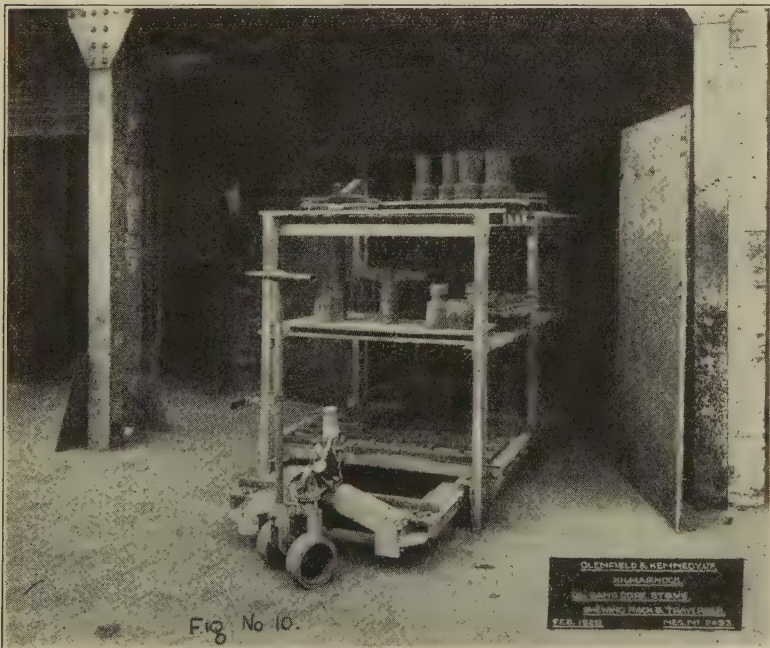


FIG. 10—OIL SAND CORE OVEN, SHOWING RACK AND TRANSFER TRUCK

with the sand mixture. It can also be adopted by remixing with a suitable core compound for dry sand facing purposes. Old cores can be passed through a rotary kiln, and the oil and carbonaceous matter removed by burning when the product is equal to new core sand. This should receive attention by those foundrymen who have to transport core sand from long distances and carry heavy freight charges. The matter becomes a practical proposition when freight charges are treble the cost of the sand at the pit.

Successful oil sand practice essentially depends upon the use of good drying stoves. This is a point often overlooked by the practical man. Oil sand dries by oxidation, and is not just a question of removing moisture, and the most successful way to bake cores is by the use of low temperature with good air circulation inside the stove. In fact, this also applies to drying of all sand molds and cores in the foundry. One has only to notice how rain soaked pavements and streets dry just as quickly under the effects of a good breeze without sunshine, as on the warmest

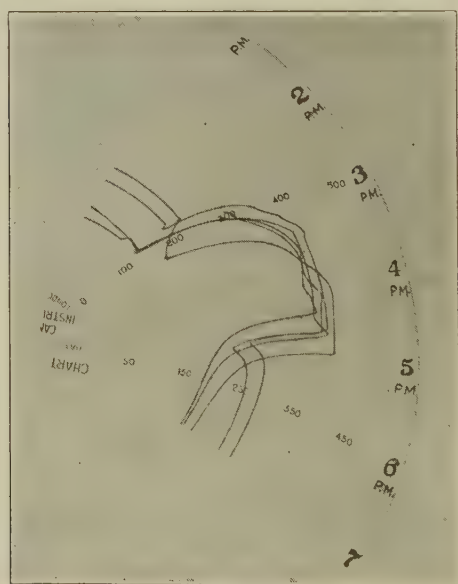


FIG. 11—TEMPERATURE RECORDER CHART OF CORE OVEN OPERATION

of calm summer days to appreciate, and understand this point. A temperature of 400 degrees Fahr. is amply sufficient to cover the drying of oil sand cores, and the quickest drying time with greatest stove efficiency is obtained by a good inside stove circulation. For this purpose the most flexible practice is to use an exhaust fan instead of the usual smoke stack or chimney. Figs. 8, 9 and 10 illustrate the general layout of a stove battery recently re-designed by the author, which has given exceptional satisfaction. The exhaust fan on the roof should be particularly noticed. The general practice is to fire one compartment at a time, while the other is being loaded, and after drying has been completed in the

Table 5

CORE DRYING EXPERIMENTS AT BAKING TEMPERATURE OF
400 DEGREES FAHRENHEIT

Cores Made from 2 Per Cent Boiled Linseed Oil and Sea Sand

Size of Core	Transverse Test in Ozs.				
	Baked ½ Hour	Baked 1 Hour	Baked 1½ Hours	Baked 2 Hours	Baked 2½ Hours
6" x 1" x 1"	288	680	648	640	...
6" x 1½" x 1½"	...	1412	1734	1720	1413
6" x 2" x 2"	...	...	1321	3236	3028

{ Baked 40 mins., 492
Baked 50 mins., 599

one stove, the firebox heat is switched over to the next compartment, while the exhaust fan has been connected up in such a manner to withdraw hot air from the stove just finished firing, as well as circulating the air in the stove being fired. This results in very quick cooling of the stoves, and consequent increased production.

Fig. 11 shows a temperature recorder chart from this battery, and particular note should be made of the steady control possible, and the saving in time of heating up and cooling down. In this stove a full load of cores can be successfully dried out, up to 3 inches in section, in 2 hours at 350 degrees Fahr. Different core-oils require different drying temperatures. For instance, linseed oil can be dried at higher temperatures than those containing molasses or glutrin, and it is of particular importance that a safe drying temperature be employed. Furthermore, to obtain the best results, it has been found that for a certain core section the drying time is of importance, and that each section has a certain drying time to give the best and most economical work-

ing. For example, in Table 5 are results obtained on this question, and taking a core of 1 inch section, using a 2 per cent linseed oil mixture, with a drying temperature of 400 degrees Fahr., the best properties are obtained in one hour. For a $1\frac{1}{2}$ inch section the best properties are obtained in $1\frac{1}{2}$ hours, while for a 2 inch section perfect drying is obtained in 2 hours. This should be easily remembered as the drying time is denoted by the thickness of the core section in inches up to 2 inches. Work in this direction will give very valuable results to the foundry, and save considerable coke and give increased production.

In conclusion, it should be clearly understood that the aim of the metallurgist is to help the practical man, and each should respect the others' efforts. The price of safety in foundry work is eternal vigilance, which can only be obtained by suitable control made possible by a mutual understandable basis of *science* hand in hand with *labor*. The future developments of the gray iron industry holds untold possibilities, and it is essential that the individual members of the foundry trade should bring themselves and their foundries under the wing of modern progress, so that those future developments can be applied to successful practical effort. The author is indebted to the management and directors of Messrs. Glenfield & Kennedy, Ltd., Kilmarnock, Scotland, for permission to publish the results in this paper.

Foremanship Training

BY A. B. PEIRCE,* CHICAGO

The growing significance of and necessity for Foremanship Training in our manufacturing industries has created a rapidly enlarging field for constructive service by forward-looking trade associations.

Much valuable assistance may be rendered member companies by first helping them to see the necessity for this work, and then by assisting them to select and install a program that is adapted to their requirements.

A broad statement, but nevertheless one which probably will not be challenged, is that no one activity has ever been so far-reaching in the field of employer-employee relations as the present foremanship training movement. The light has not been hid under a bushel, and many plans, services, and courses have been prepared by numerous publishers, privately owned schools, industrial service corporations, and professional writers. Most of those engaged in the work are conscientious; but, unfortunately, unscrupulous persons also have been attracted to the field because of the possibilities for great profit presented to professional writers. Because of this condition, extreme care is necessary when an employer decides which will be the most effective plan to adopt for his establishment. It would seem that should a trade association elect to serve its members in an advisory capacity only, there is an unlimited opportunity to help them avoid unsatisfactory experience and loss of money.

*Director, Department of Industrial Education, National Metal Trades Association
Discussion of this paper begins on page 610.

The experience of the National Metal Trades Association is typical from the trade association angle, and a brief resume should be of interest to the members of the American Foundrymen's Association.

About five years ago the Association's Committee on Industrial Education made an intensive study of the foremanship training field, including the progress accomplished up to that time. Among the various angles studied were the different methods of procedure that were being followed, existing courses, available texts, and the relative effectiveness of each.

Several definite conclusions were reached, outstanding among them being that:

(1) Unlimited benefits may be derived from a properly set up and efficiently managed program.

(2) The so-called Conference Plan produced satisfactory results more often than nearly all others combined.

(3) In many instances, the use of supplementary text or lesson sheets added to the effectiveness of programs conducted under the Conference Plan.

(4) The text materials or courses available in the open market either were unsuitable for use in metal trades plants or they were over-priced.

(5) The Committee has an opportunity to do a constructive piece of work by developing a complete program for the membership. Such a program, however, should include the necessary text material for a continuous plant activity of indefinite length.

* * *

These findings prompted the Committee to prepare our initial course, which was styled "Foremanship." This now has been supplemented by an additional publication to provide for a continuation of the plant programs established.

An early and important conclusion reached by the Committee was that a foremanship course or text should not represent the work of a single mind, but rather the associated ideas of several persons competent in this field. This accounted for the adoption of a procedure by which the preparation, revision and editing of the course, section by section, was carried on by six to

ten persons. Each person who assisted in the development of the course was a practical shop man and had been directly concerned with the problems of both men and management.

Added effectiveness was given the course by provision of a Conference Leader's Manual. The Manual is a separate book, containing information and suggestions which the Conference Leader may follow in organizing and conducting a series of plant conferences. This manual also furnishes the Conference Leader an analysis of each lesson, suggests questions for discussion, and serves as an aid in planning his program for each Conference.

This initial course purposely was made quite elementary and general in character. This was done in order to break down resistance on the part of the foremen, many of whom believe they do not need any additional training. It is, therefore, necessary to create an appreciation of the fact that there is still much for them to learn about their own jobs in the early stages of a training program.

The fifty-two lessons of the course were developed as a part of five sections which may be classified as follows: Self-Analysis, Job Analysis, Handling Workers, Principles and Policies of Management, and Production Methods. These lessons are brief, yet contain the necessary material to stimulate thinking on a given subject under discussion. Having these lessons studied previous to the meeting usually will bring out many more valuable points during the conference than would be the case if the members have made no previous preparation.

A resume of the standard practices developed for setting up and operating the National Metal Trades Association program probably will be interesting to those present, and is included in this paper for that purpose. For convenience, it is broken up under the following headings:

Attitude of the Management: The united support of the management is essential to the successful administration of a Foremanship Training Program, not only at the beginning, but throughout its entire period of presentation. There should exist a spirit of open-mindedness on the part of the management, and constantly improving conditions should be anticipated rather than

immediate drastic changes. It should be borne in mind that if the initial program is successful, the foremen may be expected to call for more. This has been our experience in most of the plants studied. The management should be willing to delegate full responsibility for the conduct of the program, either to a small committee or to the Conference Leader. This procedure provides for flexibility of the program and for greater efficiency.

Financing the Program: The entire cost of the program is, in most instances, assumed by the management. There are exceptional cases, however, where the foremen pay a part of the expense. Unless the suggestion that the foremen bear a part of it comes from within their own ranks, it is not desirable that this plan be attempted.

Executive Organization Plan: The Executive Organization Plan varies in different plants, but the one most commonly used is known as the Manager Plan. A Works Manager, Superintendent, Personnel Director, or someone of similar rank, is designated as manager. The Conference Leader is directly responsible to the manager and may take advantage of the counsel of an Advisory Committee, composed of staff experts and a leader or two from the ranks of the foremen.

The Conference Leader: The Conference Leader selected should be a man who can command the respect and confidence of the foremen without any exercise of authority. He must be able and willing to deal with all questions in a straightforward and honest manner. He must have leadership ability and be what commonly is known in industry as a high-grade man. Men holding positions as Superintendents, Assistant Superintendents, Personnel Directors, Production Managers, and others of this level are best qualified because of their association with the foremen and usually are selected as Conference Leaders.

Personnel of the Conference Group: Conference groups usually include all assistant superintendents, department heads, foremen, assistant foremen, and sub-foremen, both in the office and shop. Prospective foremen and others who are being advanced are included to a limited extent. When there are two or

more conference groups, consideration is given to rank, position, and working associations when men are assigned to the various groups.

Size of Conference Groups: The experience of many indicates that 15 to 18 constitute the ideal group. Typical enrollments range from 10 to 20, while eight is the minimum and 25 the maximum group that can be handled satisfactorily. The advantages of the moderate sized group are: better distribution of discussion; better opportunity for the leader to measure his men; better opportunity to develop backward men; good variety of experience; less cliquing; better sociability and friendly competition.

Time of Meeting: Whenever possible, it is best to hold all meetings on company time, as this assures full attendance, discovers men who are good organizers, develops understudies, and indicates a desire on the part of the management to make the program an activity worthy of serious attention. Best results are obtained when the meetings are held early in the day, preferably just before lunch.

The combination plan used in a few instances calls for attendance partly on company time and partly on the men's time, and commonly is known as the 50-50 plan. This plan has many disadvantages and should be avoided if possible. Some of the disadvantages are: doubt exists in the minds of the foremen as to the value the management places upon the program, it keeps supervisors away from their departments at quitting time, there is a noticeable uneasiness on account of clock watching which works a hardship on the Conference Leader, and men are delayed in reaching home.

Meetings held entirely on the men's time also are provided in some cases, and if a meal is furnished by the company, this plan sometimes is more satisfactory than the 50-50 plan. It promotes sociability and a good feeling for the company. On the other hand, the fatigue element is high, and it might create dissatisfaction in the homes of the group members.

Frequency of Meetings: Meetings are held either weekly, every other week, or monthly. The every other week plan seems to meet with most favor. There is time to think over and digest the discussions and records developed in one conference before starting to prepare for the next one; more time is available for preparation for the next conference; and there is less danger of the men losing interest in the program than in the case of the weekly plan. Interest sometimes lags where there is a long lapse of time between conferences, and for this reason the monthly plan is not as highly regarded.

Length of Meetings: Meetings of from an hour to an hour and a quarter have proved most satisfactory. Limitation of sessions to this length secures snappy meetings and holds the interest of the group, as the members do not tire and the leader finds it easy to stimulate discussion. Another situation which arises where sessions are limited is that many times the subject is unfinished and must be carried over until the next meeting. This permits intermediate thought and additional preparation, which produces desirable results. When sessions are too long, there is a noticeable tapering off of interest and a tendency to tire. If on company time, it keeps the men away from their departments too long at one time; and, if on the men's time, there is danger of creating an undesirable attitude toward the program.

Attendance Regulations: There is considerable difference of opinion concerning attendance regulations. There are certain advantages and disadvantages to both voluntary and compulsory attendance rules. Some advantages of the compulsory plan are: full attendance; an opportunity to develop the weak man; and an opportunity to spot the reluctant man. Some disadvantages of this method are: a lack of whole-hearted support, a possibility of dissatisfaction, and a lack of honest opinion. Some advantages of the voluntary plan are: whole-hearted cooperation is assured; it points out the progressive men; and it creates a smaller group, the progress of which is more rapid. Some disadvantages of this method are poor attendance, and lack of opportunity to work on the disinterested men.

The Conference Room and Equipment: A suitable conference room is important. The type of room does not matter if it is comfortable, easily accessible, free from disturbing noise, and isolated from interrupting devices, such as auto calls, telephones, and other signals. The room should be properly equipped with a well lighted blackboard at least four feet by eight feet in size (a larger one is more satisfactory). Comfortable chairs are a necessity, and enough tables for all to find a place to rest their elbows have been found desirable.

Visitors: Limiting the number of visitors at any one time has been found to be good practice. Visits by company executives have a good effect if their stay is limited to five minutes or less. It has been rather definitely admitted that company executives of the rank of superintendent or higher should not sit through the conferences unless they are acting as the regular Conference Leader.

Rules and Regulations Governing the Conference: The use of rules, as such, should be highly flexible, as a conference group does its best thinking when everybody is at ease. The Conference Leader assumes full charge of the sessions and is responsible for maintenance of order and dignity at all times. The leader's job is to present the subject, clarify it, and help the group to define it properly. He also presents questions for discussion and draws out all available ideas from the group members. He strives for distribution and equalization of discussion and refrains from rendering personal decisions. The good leader always endeavors to make the conference informal and avoids posing as a professor or teacher. Probably the leader's most important obligations are to respect the confidence of the group members, to avoid giving offense to any one, and to prevent gossiping. Following each conference, a Conference Leader always should prepare a report for the management, which should include only those items that relate to the important points developed during the conference.

In closing, I wish to emphasize the fact that Foremanship Training in the metal trades is not a fad. It is a necessity aris-

ing as a result of changing procession in manufacturing, the shortage of skilled help, and the ever broadening scope of the field of employer-employee relationships.

In the final analysis, we believe that the major problems of industry today are:

1. The improvement of personnel.
2. The improvement of quality.
3. The maintenance of production.
4. The reduction of costs.

We believe that the solution of these problems will be comparatively easy if we provide for an ample supply of skilled workmen and a corps of foremen and executives trained to handle human relations problems and to encourage industrial good will.

Report of Joint Committee on Refractories—Sub-Committee Survey of Gray Iron Foundry Refractories

To Joint Committee on Foundry Refractories:

Your Committee hands you herewith a report on the results of a questionnaire sent out to some 200 selected gray iron foundries.

It was deemed useless to try to get returns from the whole body of the foundrymen, and the procedure was adopted of asking each member of the Gray Iron Committee to suggest the names of the foundries in his District which he thought would be likely to furnish information of value in this survey. Copy of questionnaire pages 464 to 465 shows the information requested, and the detailed report shows the general nature of the replies received.

The data in general concerning the heat, the size and dimension of the cupolas, tuyeres, analysis, frequency of the metal, frequency of the operation, blast pressure, character of the charge, etc., have been very generally forthcoming in those reporting.

When it comes to the replies as to the analysis of the slag the information is meager, although the color is reported by most operators, which would give a very good line as to the general character of the slag.

Most of the foundries reported the character of the cupola block they were using and the kind of daub which was being used.

It will be seen that the heats per lining shows a most astonishing variation, and when these are multiplied by the number of hours per heat the variation is even more astonishing. However, it will be noted that those reporting very short lived linings consider a lining as a renewal of the melting zone, which in some cases is done every day. Others do not consider any amount of patching as a new lining, but only reline on account of the condition of the abrasion zone. Only 28 out of 55 replies give cost of lining and of these a few gave only total cost of labor and refractories and a few only refractory cost without the labor. It was a matter of great astonishment to the committee that the total cost per ton of casting, as asked for, could vary from \$0.06 per ton to \$1.58 per ton, while the cost of refractories alone varied from \$0.05 to \$1.20 per ton of castings. It is not felt that the costs are of any particular value from this questionnaire as evidently the systems for keeping cost are different in the various foundries.

Several combinations were tried in an attempt to connect cost of refractories or cost of lining with the amount of scrap used, blast pressure and temperature, as this is the most generally available complete data. The slag analysis is so scattered as not to be very useful and no other item seems comparable.

Replies to questions 21, 22 and 23 brought forth about eight replies under each heading. Those reporting peculiar conditions mentioned high scrap charges, rough charging machinery, poor coke, etc., as being the reason for their not getting any better value out of their refractories. Also several mentioned the short heat as being the cause of the high cost, as they seem to think that the wear and tear on the lining is not so much the length of time of running as it is the number of heats.

It is interesting to note that the replies to question 23 stressed careful operation, sizing of the blocks by the maker so the joints would fit tight, care in laying up the joints so that they did fit tight together, and nearly all stressed the value of even charg-

ing, good coke, good scrap, clean pig iron, careful supervision and control.

In considering the replies on the character of the refractories used, we find only one reporting a soft burn, twenty-three report a medium burn and twenty-five a hard burned block, and one foundry reports using a soft burned block in the melting zone and hard burned block in the abrasion zone.

In the matter of grind, thirty-four replied they were using a medium grind, nine a fine grind and two a course grind.

The summary of experience as represented here seems to agree very well with the experience of the refractories manufacturers; as it is probably a result of considerable experience on the part of the foundries represented it is well worth our attention.

The report is here presented with a great deal of detail and very little comment as the committee must confess that it so far has not been able to draw any pertinent conclusions from it. However, if other students are more successful they will find the committee profoundly grateful to them for bringing order out of apparent chaos.

Respectfully submitted,

JAS. T. MACKENZIE,

H. BORNSTEIN,

E. J. LOWRY.

FOOTNOTES FOR TABLES ON PAGES 462 AND 463:

- ¹ D indicates daily heats, A indicates heats on alternate days.
- ² H indicates hand charging, M machine charging.
- ³ M indicates machine cast pig, S sand cast pig, B both machine and sand cast pig.
- ⁴ P indicates by-product coke, B beehive coke.
- ⁵ L.S. indicates use of limestone.
- ⁶ S indicates soda ash flux, and fluorspar.
- ⁷ H indicates hard burn, M medium burn and S soft burn.
- ⁸ F indicates fine grind, M machine grind, and C coarse grind.
- ⁹ F indicates use of fire clay, C indicates clay where no character was given.
- ¹⁰ S indicates sand and G grout with the percentages indicated where given.
- ¹¹ M, Z indicates melting zone deterioration determined need for relining; A, Z indicates abrasion zone deterioration determined need for relining.
- *Only burning zone considered.
- †Do not slag.
- ‡Use Fluorspar occasionally.

1—Foundry No.	2—Length of heat in hours	3—Temperature, degrees Fahr.	4—% silicon	5—% manganese	6—% phosphorus	7—% carbon	8—Frequency of operation ¹	9—Pressure in ounces	10—Size of shell, inches	11—Stack diameter, inches	12—Diameter of bush or at tuyeres	13—Lower tuyere ratio	14—Upper tuyeres	15—Charged, hand or machine ²	16—Total charge	17—% steel	18—% cast iron scrap	19—Gates and sprues, cleaned or not	20—Pig iron, machine or sand cast ³
1	6	2500	2.00	.50	.20	3.50	D	12	46	28	33	2.9	No	H	1000	20	40	No	M
2	1	.....	2.00	.45	0.45	3.34	D	12	54	36	B	2.1	No	H	2000	None	67	No	M
3	9	.....	2.80	.65	.20	3.30	A	16	72	36	24	2.8	No	H	1000	10	60	50%	M
4	2	2400	1.90	.60	.25	3.05	D	9	54	42	42	3.2	No	H	2000	15	50	50%	B
5	3	2600	1.25	.60	.70	.....	A	11	60	42	42	3.6	No	H	1500	10	40	Yes	S
6	3	2700	1.75	.40	.70	3.65	D	12	60	42	42	2.6	No	H	2000	5	30	Yes	B
7	5	2650	2.60	.58	.45	3.50	A	9	60	42	40	.....	No	H	1500	15	50	No	M
8	2	.....	2.30	.60	.30	3.30	D	.....	60	48	48	5.7	No	H	2000	15	60	No	M
9	5	2500	2.15	.65	.44	3.50	D	.....	60	48	48	2.7	No	M	1600	7	50	No	M
10	8	2700	2.40	.75	.20	3.45	A	12	63	46	38	4.4	No	H	1500	10	40	No	M
11	6	.....	.....	.....	.....	.....	D	14	64	46	46	3.5	No	..	3300	15	..	No	M
12	3	2600	1.50	.50	.30	3.50	D	15	65	45	45	2.4	No	H	4000	15	35	No	M
13	2	.....	2.00	.60	.40	3.27	D	10	67	48	48	8.2	No	H	2000	No	60	Yes	M
14	2.5	2700	2.25	.60	.35	3.55	D	9	72	48	48	1.5	No	H	1500	5	46	Yes	M
15	9	2460	2.628	.516	.514	1.936	A	9	78	48	42	...	Yes	M	2000	No	72	No	S
16	2	2600	2.10	.60	.60	3.30	D	16	72	54	54	4.0	Yes	H	3000	5	50	No	M
17	6	.....	.....	.....	.....	.....	D	16	72	54	54	7.5	No	M	3300	100	..	No	M
18	9	.....	2.20	.70	.20	3.40	D	14	72	54	45	2.0	Yes	H	1500	25	40	No	M
19	8	2700	1.60	.40	.70	3.60	A	12	72	54	54	4.8	No	H	3000	8	30	Yes	S
20	9	2600	1.70	.55	.40	3.65	D	13	72	54	43	3.5	No	H	4000	No	40	No	M
21	2.5	2600	1.85	.60	.54	3.00	D	14.5	78	50	50	2.3	No	H	3000	3	..	No	M
22	10	2600	2.00	.65	.20	3.50	D	14	72	55	55	5.2	No	B	1200	15	45	No	B
23	2.5	2700	1.75	.60	.25	3.60	D	6	72	54	48	7.9	No	H	3000	10	40	No	M
24	3	.....	2.00	.55	.57	3.60	D	12	76	..	54	2.6	No	M	3000	2	40	No	M
25	7.5	2550	1.75	.50	.18	.....	D	14	78	60	..	2.0	No	H	1500	15	..	Yes	M
26	9	2600	2.20	.65	.15	3.40	D	11	78	60	..	2.4	No	H	2500	13	50	No	M
27	3	2750	2.10	.55	.40	3.25	D	15	78	62	58	...	No	M	3000	25	50	No	M
28	9	2650	2.40	.55	.18	3.20	A	14	84	60	..	...	Yes	B	4000	17	45	No	M
29	8	2600	2.25	.60	.25	3.30	D	11	84	60	60	...	No	H	3000	10	40	No	B
30	10	.....	2.00	.60	.72	3.40	A	11	90	60	54	3.9	Yes	H	2000	2.5	..	No	M
31	2.5	2750	2.05	.62	.73	3.36	D	12	84	64	64	...	No	H	3000	5	45	No	B
32	7	.....	2.40	.55	.55	3.45	D	12	84	66	58	1.4	No	H	3500	4	..	No	M
33	4	.....	1.50	.50	.20	3.40	A	16	84	66	60	6.2	No	H	4200	20	35	Yes	M
34	5	2700	1.75	.60	.25	3.60	D	7	84	72	60	7.9	No	H	3000	10	40	No	M
35	6	2550	2.40	.70	.20	3.30	A	25	90	66	60	2.4	No	M	3000	20	..	No	B
36	10.5	2560	1.10	.37	.05	2.70	D	6	90	66	54	2.1	No	H	4000	40	40	Yes	M
37	7	.....	2.50	.60	.65	3.35	D	18	90	68	68	2.6	No	M	3000	No	25	Yes	M
38	9	2750	2.25	.55	.25	3.30	D	12	92	68	68	5.0	Yes	M	4000	10	40	No	M
39	4.5	.....	1.85	.60	.60	3.40	D	10	90	70	70	1.6	Yes	H	3000	..	40	No	M
40	8	2600	2.30	.65	.75	3.40	D	16	96	83	72	3.6	Yes	M	3500	10	..	Yes	B
41	11	2600	1.70	.50	.45	3.65	D	12	90	72	61	4.1	No	H	4000	No	40	No	M
42	8	2650	2.20	.60	.16	3.35	D	..	90	72	64	5.2	No	H	3000	15	45	No	M
43	8	2800	1.80	.63	.56	3.41	D	12	96	72	72	3.2	No	H	4000	1	..	No	M
44	9	2600	1.60	.40	.70	3.65	D	15	96	72	72	5.2	No	M	6500	2	20	No	B
45	20	2700	1.60	.50	.70	3.55	A	20	96	72	72	5.2	No	M	6000	15	15	No	B
46	6.5	2600	1.85	.60	.50	.....	D	10	96	72	72	5.2	Yes	M	3600	3	11	No	M
47	4	2550	2.30	.47	.....	.....	D	16	96	72	60	3.1	No	M	4000	..	50	..	B
48	10	2700	2.30	.75	.20	3.35	A	22	96	72	60	3.6	No	M	4400	17	35	No	B
49	6	2500	1.75	.60	.50	3.50	A	13	96	72	72	4.0	No	M	4000	5	25	No	S
50	9	2600	2.00	.60	.40	3.50	A	10	96	74	74	9.9	Yes	M	4500	7.5	30	No	M
51	4.5	.....	.....	.....	.....	.....	D	10	92	76	76	...	No	H	6000	No	10	No	B
52	3.5	2625	1.40	.50	.20	3.85	D	20	96	78	66	3.6	Yes	M	4000	No	35	No	M
53	11	2650	1.75	.60	.60	3.60	A	11	108	72	..	1.6	Yes	M	8000	No	40	Yes	B
54	12	2400	.90	.32	.15	3.15	A	13	108	72	68	3.3	No	M	6000	10	45	No	M

Footnotes on page 461.

21—% coke between charges	22—Height of bed, inches	23—Type of coke ⁴	24—% ash in coke	25—% flux based on wt. of iron	26—% CaCO ₃ in flux ⁵	27—% fluor spar	28—% FeO in slag	29—% SiO ₂ in slag	30—Color of slag	31—Character of burn of blocks ⁷	32—Character of grind of blocks ⁸	33—% daubing clay used ⁹	34—Sand or grog used ¹⁰	35—No. of heats per lining	36—Hours heats per lining	37—Point determining relining ¹¹	38—Total cost per ton of castings daubing and lining	39—Refractories cost per ton of castings
14 36	11 50	P	..	4	L.S.	S, 0.2	..	..	..	H	..	F, 50	S, 50	350	700	M, Z	..	..
10 36	13.5 40	P	10	†	L.S.	No	..	..	Black	M	M	F, 15	S, 50	300	300	M, Z	0.67	..
7 34	12.5 38	B + P	9	4	L.S.	No	..	..	Dark	M	M	F, 33	S, 33	85	180	M, Z	..	..
11 32	10 32	P	10	3	L.S.	No	..	..	Black	M	M	F, 67	S, 33	250	750	M, Z	0.17	0.07
14 36	10 32	B	10	3	L.S.	No	5.0	50	Black	M	M	F, 50	S, 50	100	500	M, Z	..	..
10 32	9 36	P	8	3	96	No	3.5	46	Black	M	M	F, 100	S, 33	140	280	M, Z	..	..
9 36	12 46	P	8	4	52	No	15	36	Black	M	M	F, 100	S, 33	325	1625	A, Z	0.51	0.25
14 36	12 46	P	8	3	97	†F	..	21	Olive	H	M	F, 40	S, 60	75	600	M, Z	0.47	0.22
12 60	10 30	P	11	3	90	S, 0.4	5	43	(Dark Brown)	H	F	F	..	160	480	M, Z	..	..
10 30	9 32	P	9	1.5	97	No	24.5	56.2	Black	H	M	10	S, 90	175	150	M, Z	0.48	0.30
6.2 ..	10 32	P	7	3	95	No	12.5	45	Black	H	M	F, 50	S, 50	225	560	A, Z	0.25	0.12
10 36	14 36	P	8	..	L.S.	..	..	..	(Brown)	..	..	F, 33	S, 67	1*	9	M, Z	1.68	1.20
14 46	10 40	P	9	3	L.S.	F, 0.3	..	..	Black	H	M	F, 25	S, 50	40	72	M, Z	..	0.13
10 40	10 40	P	10	3	95	No	5	45	Brown	M	M	F, 60	S, 40	150	1200	M, Z	0.20	0.10
10 30	11 40	B	11	2	92	No	3	48	(Green Light)	M	M	F, 100	..	..	..	M, Z	..	..
11 40	10 45	P	..	3	L.S.	No	..	..	(Brown Dark)	S	M	F, 33	S, 67	200	500	M, Z	..	..
10 45	13 42	P	9	2.5	92.3	No	3.2	41	(Green Gray)	M	M	F, 67	S, 33	80	800	M, Z	..	..
9 50	11 35	P	9	2	97	No	16.7	50	(Green Black)	H	F	F, 100	S, 90	190	475	A, Z	0.30	0.15
11 35	10 42	P	10	4	D, 60	No	..	..	(Dark Green)	H	M	F, 10	S, 90	150	450	A, Z	..	..
10 42	11 36	P	7	3	L.S.	No	..	..	(Green Black)	M	M	F, 50	S, 50	150	120	M, Z	..	..
10 46	11 36	P	9.5	3	88	No	..	..	(Black)	H	F	F	M, S	300	2700	A, Z	0.37	0.15
10 48	10 48	B	9	No	99	No	..	..	(Black)	H	M	F	S, 33	75	225	M, Z	0.40	..
10 ..	11 40	P	..	2.5	L.S.	No	4.8	38	(Green Gray)	H	F	F, 67	S, 33	..	..	A, Z	0.48	..
11 33	7 41	P	7	3	55	..	..	..	(Black Dark)	..	..	C	S	150	1200	M, Z	..	..
11 46	11 40	P	..	2	D, 50	No	3	50	(Blue Dark)	M	C	F, 67	S, 33	75	750	A, Z	0.415	0.255
13 42	11 46	P	7.5	3	96	S, 0.1	..	..	(Brown Black)	M	F	F, 70	S, 30	300	525	M, Z	..	0.17
11 40	13 42	P	..	2	97	No	..	..	(Dark Green)	H	F	F	S	60	240	M, Z	..	..
13 42	14 42	P	9	2	97	No	16.7	50	(Olive Brown)	H	F	F	..	11*	55	A, Z	0.32	0.18
7.5 40	14 42	P	9	2	95	S, 0.1	5	50	(Black Greenish)	M	M	F, 50	S, 50	190	950	A, Z	..	..
11 40	10 46	P	8	3	95	No	5	45	(Black)	..	..	F	S & G	25	260	A, Z	0.38	0.29
9 46	10 ..	B	10	3	D, 60	No	..	..	(Black)	M	M	F	S	60	540	M, Z	0.68	0.37
13 42	10 42	P	7.5	2	L.S.	S, 0.1	9	45	(Black Dark)	H	M	F	S	250	1125	M, Z	0.26	..
10 30	13 50	P	11	2	95	No	3	48	(Green Dark)	M	M	F	G	90	720	..	0.32	0.24
13 50	11 70	P	11	2.5	91	No	4	38	(Brown Dark)	M	M	F, 30	S, 20	190	1520	A, Z	..	..
10 36	12.5 42	P	10	3	95	No	5.0	40	(Green Brown)	M	M	F, 60	S, 40	200	1800	A, Z	0.20	0.10
11 36	10 31	B	11	1.5	L.S.	No	3.8	40	(Green)	M	M	F, 60	S, 40	70	1400	A, Z	0.24	0.12
12.5 48	10 31	B	11	1.5	L.S.	No	1.2	42	..	H	M	C	M, S	280	1760	M, Z	..	..
10 30	10 30	P	11	3	86	No	2	45	(Green Black)	H	M	F, 33	S, 67	150	50	..	..	0.15
10 30	11 30	P	11	3	94	No	..	..	(Dark Gray)	H	M	C	G	100	600	A, Z	0.06	0.05
11 30	10 42	P	9	2	96	No	10.5	45	(Dark Gray)	M	M	67	S, 33	11	99	A, Z	0.34	0.25
15 60	10 42	P	9	2	96	No	..	..	(Dark Green)	H	F	F, 80	S, 20	150	675	M, Z	..	..
10 30	15 60	B	11	2	95	No	3	41	(Dark Green)	M	M	F	M, S	..	..	M, Z	..	..
10 48	12 48	P	10	2.5	53	No	15	42	(Black)	H & S	M	F	..	150	1650	A, Z	0.25	0.15
12 48	12 48	P	9.5	2.5	88	No	8	59	(Black)	..	..	F, 50	S, 50	150	1800	A, Z	0.23	0.05

Questionnaire*Joint Committee on Foundry Refractions**GRAY IRON SURVEY*

1. Name and address of foundry
2. Title of firm representative replying to questionnaire.....
3. Number of cupolas.....
4. Size of heat Length of heat
 Temperature of iron as tapped
 Analysis
 Silicon Manganese
 Phosphorus Carbon
5. What class of castings are poured?
6. Do you tap or run continuously?
7. How often do you run a cupola, daily every other day
 or what?
8. What is your blast pressure?
 What is your blast volume?
9. What is the diameter of your shell?
 What is the thickness of lining?
10. Is your lining straight or boshed and if boshed state how?
11. How many lower Tuyeres?
 Cross section of Tuyeres at smallest point?
 Cross section at largest point?
 Do you use upper Tuyeres? What size?
 How are they spaced relative to the lower tuyeres?
12. Do you charge by hand or by machine, and if the latter, what kind of
 machine?
 What is the total weight of iron per charge?
 How much steel, and is it light, medium or heavy?

 How much cast scrap and is it clean or dirty (please be specific about
 gates, sprues, etc., as to whether they are cleaned or not)?

 Is pig iron sand or machine cast?

13. How much coke per charge, and how much ash does it contain?
.....
Is it by-product or beehive?
Is it well sized? Is it hard, medium or soft?
..... Is it strong or fragile?
14. Do you slag? What flux is used principally?
.....
What is its analysis, especially calc. carb.?.....
Mag. carb. How much per charge?
Do you use any of the soda fluxes, and how much?
What is the approximate analysis of your slag, especially silica
..... lime..... iron oxide
manganese oxide? Is it solid or porous, and what color
is it when slowly cooled?
.....
15. Do you charge coke, iron, and stone at one time or separately?
.....
Do you load pig iron into charging boxes by hand or with magnet?
..... If you use magnet do you take any steps
to get rid of the shot and oxides which are picked up with the pig?
.....
Is there much of this material on the pig?
16. Do you line with blocks which fit your shell?
Do you use the same block all the way to the charging door?
..... What kind of block do you use, soft
..... medium or hard rimmed?
Coarse medium or fine grind?
Do you use single lining or double?
Do you use stiff mud or thin batter, and what is the character of the
clay used for laying blocks?
.....
How long do you dry a new lining before using?
17. What do you use for daubing?
and how do you mix and apply it (please answer fully)
.....
.....
Is cupola well chipped out before daubing?
Do you use a gauge stick to insure correct finished diameter?
Do you have a responsible man in charge of the cupolas?
and does he personally supervise the daubing?
18. How many heats do you get out of a lining?
What point in the stack usually determines the need of a new lining?
..... Who determines when a new lining is necessary?
.....

19. How high above the top of the mantel plate are the following:
Tap hole (bottom of) Sand bottom (back of)
..... Slag hole (bottom of)
Bottom of lower tuyere Bottom of upper tuyere
..... End of bosh
Top of coke bed when charging is begun.....
Bottom of charging door
20. What do your refractories cost per ton of iron melted?
How much of this is lining materials?
Lining labor?
Daubing materials?
Daubing labor?
21. Please give any other data you think may be relevant and state why
.....
22. Do you have any peculiar or outstanding feature of your practice you
think worth mentioning?
23. What are your suggestions for the improvement of cupola refracto-
ries or for obtaining better service from what is available?
.....
.....
.....
.....

Report of Sub-Committee on Pig Iron

This report covers the progress of the sub-committee on Pig Iron over the period of 1928.

a. The work of this sub-committee has been temporarily held up awaiting the development of a method for the evaluation or comparative tests for pig irons. Until such a "measuring stick" has been adopted it will be impossible to proceed rapidly with the work.

b. Any statements as to the comparative values of pig iron at present are merely matters of opinion and, therefore, are incapable of proof.

c. Up to the present time, the only tangible work performed along this line was done by a blast furnace not operating in conjunction with this committee, and which included the varying of scrap from zero to twenty per cent in the furnace burden. Fifty pound samples of each cast made during these runs are being reserved for future tests.

d. The attention of the committee has been called repeatedly to the increased number of complaints caused by excessive wear in castings in various lines of work, e. g., cylinders, liners, gears, rings, sleeves, and discs. The question has been raised often as to whether this is due to the quality of pig iron now made. It would seem to this committee, that this trouble is of sufficient importance to warrant the attention of the American Foundrymen's Association and that investigation should proceed to determine some method of test which would indicate the value of various irons in their resistance to wear.

e. The activities of this committee have been confined to discussions leading to suggestions as to what affected the pig iron produced. Among the items now under consideration are:

1. Humidity of blast.
2. Slag analysis.
3. Reducibility of the ore.

4. Temperature of iron as tapped.
5. Size, analysis and structure of coke.
6. Temperatures of the working furnace.

f. The committee again wishes to express their belief that the above investigations can and should be made only with the co-operation of the American Blast Furnace Association.

Respectfully submitted,

R. S. MACPHERRAN, *Chairman*,
E. J. LOWRY,
J. T. MACKENZIE.

High Strength Cast Iron

By F. B. COYLE¹ AND D. M. HOUSTON,² NEW YORK, N. Y.

As compared with other ferrous materials currently used for castings, gray cast iron possesses several important advantages. It is cheap, and it may readily be cast into intricate patterns without serious difficulty with shrinkage or porosity. In addition, it is easily machined, and it has a high degree of wear resistance. On the other hand, its tensile strength, which at best ranges from 35,000 to 45,000 pounds per square inch, is definitely inferior to that of either cast steel or of malleable iron. Its ductility in comparison with the same materials is also quite low, in fact, practically nil.

Many engineers have expressed the opinion that if it were possible to obtain a cast iron with strength considerably above that of even the best grades of cast iron or semi-steel formerly obtainable, it could be used extensively where ductility was not essential but where strength and resistance to wear were desirable. Such a material would be cheaper than its competitors, steel and malleable iron, could be more readily cast and would constitute a very useful addition to our present ferrous casting materials. It would be intermediate between ordinary plain iron and steel. This demand has been reflected in recent years by renewed activity in the development of processes for producing cast iron with high strength.

Within the past few years the authors have developed* a high strength iron which appears to have substantial promise of occupying the position indicated above. A full description is given below. This iron can be readily produced to exhibit a tensile strength over 50,000 lbs. per sq. inch (in arbitration bars)

¹ Research Metallurgist, The International Nickel Co., Inc., Bayonne, N. J.

² Deceased, formerly Foundry Engineer, The International Nickel Co.

*This product and the process for producing it were conceived and demonstrated by F. B. Coyle and patent applications covering it are pending in his name. D. M. Houston had been very active and indeed instrumental in developing its manufacture and use in industrial foundries.

Discussion of this paper begins on page 729.

and may be readily cast and machined. It is produced preferably in the cupola by melting a charge consisting largely of steel.

Limits of Strength in Plain Cast Iron

The question, to what extent must the strength of cast iron be increased to satisfy this demand, naturally arises. This feature must necessarily be controlled by the limits of strength obtainable in cast iron by normal methods. Naturally, the first consideration is composition. Of the elements which affect the strength and structure of cast iron, carbon and silicon are important. Fig. 1 shows a diagram,^{3 4} of the relation of carbon and silicon to the

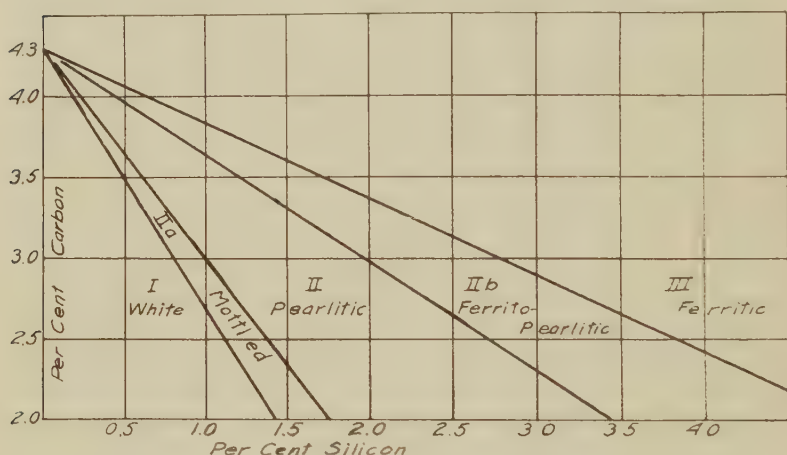


FIG. 1—CONSTITUTIONAL DIAGRAM FOR PLAIN CAST IRON—MAURER.

structure of normal cast iron and is known as the Maurer Diagram. The various areas represent the structure of cast iron of compositions within that area when cooled under ordinary sand casting conditions. However, by accelerating or retarding the rate of cooling the structure of an iron corresponding to one area may be made to correspond to the structure of another area although the chemical composition is unaltered. The proportions of carbon and silicon included in area I will normally produce a white or chilled structure. The compositions included

³ Maurer, *Kruppsche Monatshefte*, July, 1924.

⁴ F. B. Coyle, *Properties and Heat Treatment of Cast Iron for Diesel Engines*, A. S. S. T., Sept., 1927.

within the area IIa will give a mottled structure; that is, one consisting of patches of white iron and pearlite with some graphite. The proportions of carbon and silicon in area II will give a structure consisting of pearlite and graphite. In area IIb the structure will consist of pearlite, ferrite and graphite with the pearlite in excess of ferrite. In area III the structure will consist of pearlite, ferrite and graphite with the ferrite in excess of pearlite.

It is natural to assume that structure will have some bearing upon the strength of cast iron as well as composition. In a limited

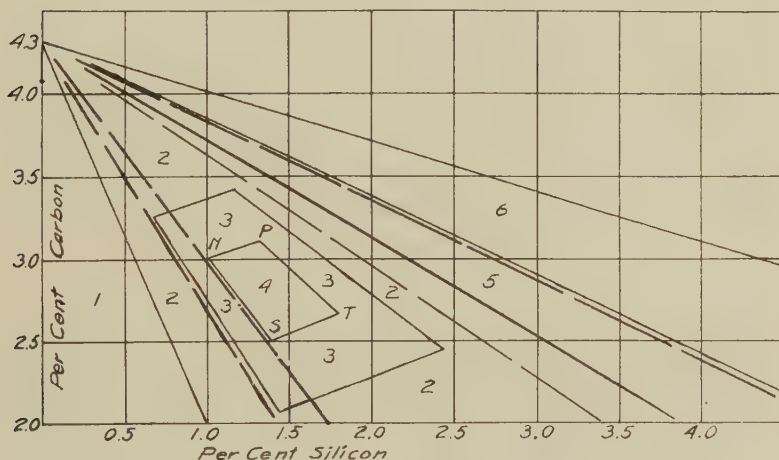


FIG. 2—CONSTITUTIONAL AND TENSILE STRENGTH DIAGRAM.
PLAIN CAST IRON.

Heavy broken lines—Maurer diagram.

Light solid lines—Superimposed strength diagram.

manner this is true as shown⁵ by Fig. 2. In the construction of this diagram the results of over three thousand tensile tests conducted during a period of ten years were superimposed upon the Maurer diagram. Each point was plotted according to silicon and carbon, but given a designating mark denoting a range of tensile strength. The ranges included a variation of 5,000 pounds per square inch. After the various points were plotted it was

⁵ F. B. Coyle, *Properties and Heat Treatment of Cast Iron for Diesel Engines*, A. S. S. T., Sept., 1929.

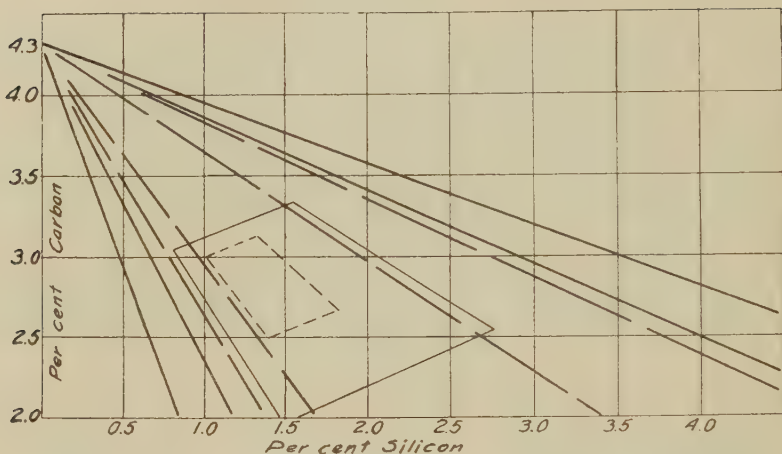


FIG. 3

CONSTITUTION AND STRENGTH DIAGRAM OF NICKEL CAST IRON.

Heavy broken lines—Maurer diagram. Heavy solid lines—Maurer diagram modified by 2% of nickel. Light broken lines—Area of maximum strength plain iron. Light solid lines—Area of maximum strength, 2% nickel iron.

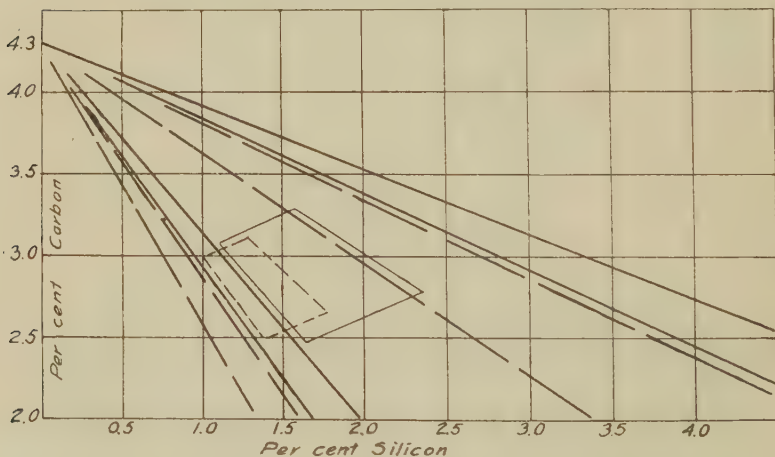


FIG. 4

CONSTITUTION AND STRENGTH DIAGRAM OF CHROMIUM CAST IRON.

Heavy broken lines—Maurer diagram. Heavy solid lines—Maurer diagram modified by 0.50% to 0.75% chromium. Light broken lines—Area of maximum strength, plain iron. Light solid lines—Area of maximum strength with 0.50% to 0.75% chromium.

possible to mark off areas corresponding to ranges of tensile strength, as given in Table 1.

Table 1

Area	Tensile Strength, Lbs. Per Sq. In.
1	Under 30,000
2	30,000 to 35,000
3	35,000 to 40,000
4	40,000 to 45,000
5	25,000 to 30,000
6	20,000 to 25,000
7	Under 20,000

Since in the present discussion high strength is the primary subject, attention will be focused on the area NPTS of Fig. 2. If the melting conditions are good, proportions of carbon and silicon included within this area will give a tensile strength in arbitration bars between 40,000 pounds per square inch and 45,000 pounds per square inch when the castings are cooled at normal rates. This represents the maximum strength obtainable with plain cast iron. It will be noticed that the area NPTS falls within the area of pearlite iron but this diagram also shows plainly that a pearlitic structure does not necessarily correspond with maximum strength.

Limits of Strength Extended in Alloy Irons

Since the limits of strength of plain cast iron have been established it is natural to turn toward the simple use of alloys in order to further extend the range available. Fig. 3 shows a diagram similar to Fig. 2 but is for iron containing 2.0 per cent of nickel. The heavy broken lines show the position of the lines of the Maurer diagram and the light broken lines the area of maximum strength in plain iron. The solid lines indicate the corresponding modifications produced by 2.0 per cent of nickel. The areas of white iron and ferritic iron are reduced and the pearlitic area increased considerably. The area of maximum strength is extended slightly into the region of lower silicon and higher carbon but extensively into the region of higher silicon and lower carbon.

Fig. 4 shows in a similar manner the effect of 0.50 per cent to 0.75 per cent of chromium. The white iron area is increased and the ferritic area decreased correspondingly. The pearlitic area is approximately the same as in plain iron but is shifted into the region of higher silicon. The range of carbon and silicon corresponding with maximum strength is about half again as

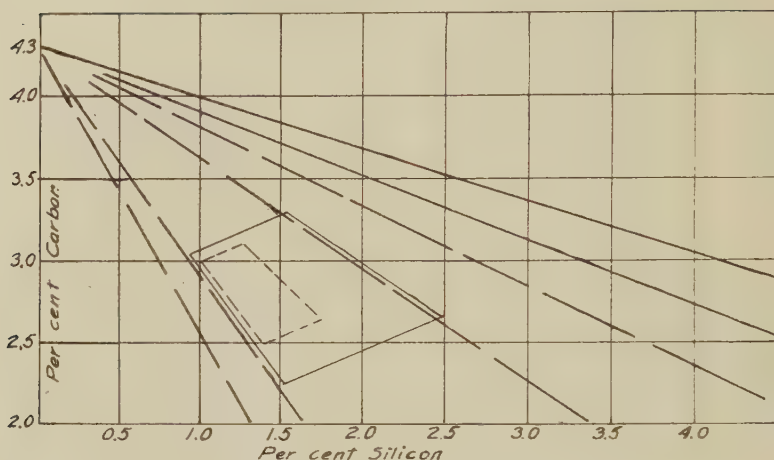


FIG. 5—CONSTITUTION AND STRENGTH DIAGRAM OF NICKEL-CHROMIUM CAST IRON.

Heavy broken lines—Maurer diagram. Heavy solid lines—Maurer diagram modified by 0.25% to 0.50% nickel and 0.25% to 0.50% chromium. Light broken lines—Area of maximum strength, plain iron. Light solid lines—Area of maximum strength with 0.25% to 0.50% nickel and 0.25% to 0.50% chromium.

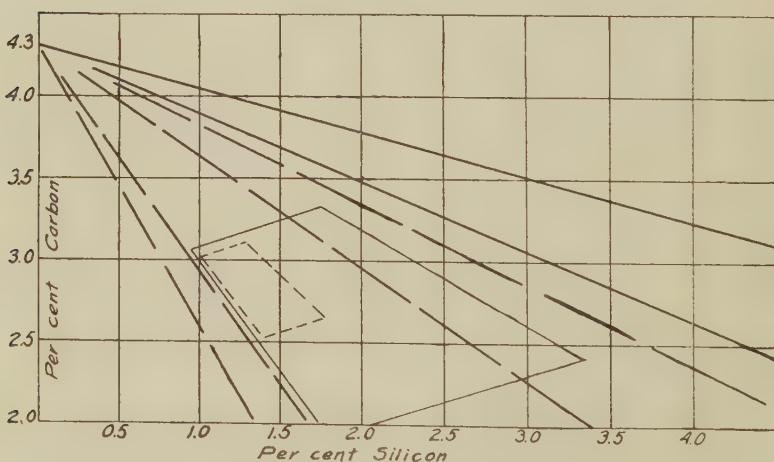


FIG. 6—CONSTITUTION AND STRENGTH DIAGRAM OF NICKEL-CHROMIUM CAST IRON

Heavy broken lines—Maurer diagram. Heavy solid lines—Maurer diagram modified by 0.50% to 1.25% nickel and 0.25% to 0.75% chromium. Light broken lines—Area of maximum strength, plain iron. Light solid lines—Area of maximum strength with 0.50% to 1.25% nickel and 0.25% to 0.75% chromium.

large as for plain iron and is shifted into the range of higher silicon. The area is shifted only slightly into the ranges of higher and lower carbon.

In Fig. 5 the effect of nickel and chromium in equal amounts (0.25 per cent to 0.50 per cent) is similarly shown. The area of white iron remains the same as in the Maurer diagram but the pearlitic area is considerably extended. The area of maximum strength is extended slightly into the range of higher carbon, appreciably into the range of lower carbon, and extensively into the range of higher silicon. The lower limits of silicon are the same as for plain iron.

Fig. 6 shows, in a like fashion, the effect of higher contents of both nickel and chromium but with the nickel in the proportion of 1.5 to 2.0 times that of the chromium. As in Fig. 5 the white iron area is the same as in the Maurer diagram. In this respect the chromium has acted to counteract the effect of nickel. The pearlite area has been decidedly increased. Here the nickel and chromium have acted jointly. The area of maximum strength has been extended only slightly into the region of higher carbon. The limits of lower silicon are the same as for plain iron. However, this area has been greatly extended into the region of higher silicon and lower carbon.

These diagrams show that the use of alloys extends the range of composition which in gray iron will produce the maximum strength obtainable by ordinary methods. However, they do not show to what extent the strength is augmented. Of course the gain in the extended region of higher carbon and silicon is considerable but the gain in the range of carbon and silicon giving maximum strength in plain iron is only slight, about 3,000 pounds per square inch, the maximum being only about 48,000 pounds per square inch.

Possibilities of Heat Treatment

Since it is not possible to appreciably increase the strength of cast iron by simple methods, the necessity of resorting to special means is apparent. It is possible to produce high strength by casting a white iron and then heat treating it. This amounts to a malleablizing treatment in which the process is interrupted before malleablizing is complete. Plain iron low in silicon can be

cast from the cupola or iron low in both silicon and carbon can be cast from the air furnace. Subsequent annealing will cause the iron carbide to break down into pearlite and graphite. If the annealing treatment is carried on only long enough to reduce the combined carbon to the amount necessary to insure a full pearlite matrix, a superior cast iron can be obtained. It will be wear resistant but will lack ductility. The strength will range from 45,000 pounds per square inch to 52,000 pounds per square inch. This is not much of a gain in strength. Piwowarsky⁶ has shown that if a similar process be carried out on iron containing appreciable amounts of nickel and chromium, extremely high strength can be obtained. Some tensile tests ranged as high as 100,000 pounds per square inch. Such processes are usually accompanied by difficulties, particularly shrinkage which invariably accompanies the casting of white iron. Serious trouble is encountered from cracking of castings in the sand. The multiplicity of operations also involves increased expense.

The New Method Proposed

Probably the cheapest and easiest method of producing high strength cast iron involves melting the metal in a cupola with, at least, only slight differences from ordinary practice and pouring the metal direct into molds to produce gray castings with the properties desired. Two basic conditions have been found to control the production of high strength cast iron. The first is that carbon should be lower than obtained in cast iron produced by conventional methods; the second is that carbon must be present as very fine, evenly distributed graphite. The carbon content should be preferably between 2.50 per cent and 3.10 per cent. This is low but it can be consistently obtained. The silicon can vary between 1.25 per cent and 4.00 per cent. While high strength can be obtained without the use of alloys, the gain in strength is inconsiderable in comparison with that obtained by the use of nickel or nickel supplemented by other alloys. Nickel can vary between 1.0 per cent and 4.5 per cent. Other alloys can be used to supplement nickel for special purposes. The particular composition used will depend upon the strength desired and the use to which the castings will be submitted.

⁶ E. Piwowarsky. *Proc. Inst. Brit. Foundrymen.*, 1926-27.

In order to obtain the desired low carbon it is necessary that the charge consist of at least 75 per cent of steel scrap. The balance can be either cast iron scrap or high strength return scrap. It may be necessary to also charge some ferro-manganese and ferro-silicon. The charge should be so adjusted that the silicon of the metal as it leaves the cupola should not be more than 0.75 per cent and the manganese between 0.50 and 0.80 per cent. This will insure a thoroughly deoxidized and degasified melt. Nickel can be charged in the cupola or added in the ladle. If the nickel is charged in the cupola the silicon in the charge should be reduced to allow for the graphitizing action of the nickel. It is preferred that the nickel be charged in the ladle. The total carbon being low it is necessary that the charge be melted hot. To accomplish this it is necessary to depart slightly from normal cupola practice. The coke bed should be higher—not less than 48 inches above the tuyeres. The exact height will depend upon the construction of the cupola and the amount of natural draught therein. The bed of coke being completely burnt through, the metal and coke charges are added. A period of soaking to thoroughly heat the cupola follows before the blast is put on. This period is usually one hour. The preheating during

Table 2

HEAT No. 3080

Weight coke in bed, 425 pounds; height of coke bed above tuyeres, 54 inches; metal charges start 8:07 A. M., stop 8:15 A. M.

Charges (2) each: 450 pounds open hearth steel discs, 50 pounds open hearth 60-lb. rails, 9 pounds ferro-silicon (50%), 3¾ pounds ferro-manganese (80%).

Ladle additions (2) each: 7¼ pounds powdered ferro-silicon (85%), ¾ pound powdered ferro-manganese (70%), 12½ pounds F Nickel shot.

Calculated composition of base melt, per cent:

Mn.	P.	S.	Si.
0.54	0.03	0.08	0.72
(Mn., 40% loss; Si., 30% loss)			

Calculated composition of treated melt, per cent:

T. C.	Mn.	P.	S.	Si.	Ni.
2.75	0.65	0.03	0.08	2.01	2.30

Analysis of castings, per cent:

	T. C.	Mn.	P.	S.	Si.	Ni.
3080-1.....	2.89	0.53	0.033	0.097	2.02	2.44
3080-2.....	2.78	0.49	0.029	0.087	1.79	2.88

Blast on, 9:11 A. M.; period of soaking, 56 minutes; volume of blast, 37,000 cubic feet per hour; first iron, 9:17 A. M.; fast iron, 9:19 A. M.; First tap, 500 pounds, 9:35 A. M.; second tap, 500 pounds, 9:44 A. M.

Physical tests:

No.	3080-1	3080-2
Transverse	6200	5920
Deflection	.153	.142
Tensile	66,200	68,000
Brinell	269	269

the soaking period aids high melting temperature and fast melting. The volume of air used should be slightly greater than normal but not so high that the metal will be oxidized. If the melted metal were cast directly the castings would be white. While the metal is flowing over the spout into the ladle ferro-silicon or ferro-silicon and nickel are added to cause the iron carbide to decompose and precipitate graphite. Castings made from this metal will be gray and possess the property of exceptionally high strength. In Table 2 is a record of a heat produced in the 23-inch cupola operated in the Bayonne foundry of the International Nickel Co., Inc.

Physical Properties

To engineers the phase of chief importance is, what are the properties of this material? These will be taken up in order and refer to nickel bearing irons.

Transverse Strength

The transverse breaking load of arbitration bars will vary between 4,500 pounds and 8,000 pounds according to chemical composition. The corresponding deflection will vary from 0.110 inch to more than 0.250 inch.

Tensile Strength

The tensile strength of arbitration bars will vary between 50,000 pounds per square inch and 70,000 pounds per square inch, depending upon chemical composition. It has been found that tests taken from gates attached to castings usually show a strength appreciably greater than that obtained upon accompanying arbitration bars.

Yield Point

The yield point of ordinary high test iron (according to A.S.T.M. specifications) and of gray iron is very low. The type of iron being described possesses a definite yield point close to the ultimate strength. This property has been definitely established by stress-strain diagrams and is also apparent by the "drop of the beam" at about 200 pounds below the transverse breaking load and 4,000 pounds per square inch to 12,000 pounds per square inch (depending upon the exact composition) below the ultimate strength in tension.

Compressive Strength

The compressive strength varies between 165,000 and 190,000 pounds per square inch. It is approximately 3.3 times the tensile strength.

Elastic Limit

This material also exhibits a true elastic limit, a property not possessed by ordinary gray iron. The elastic limit is 2 to 3 times greater than that of high test cast iron, and in tension varies between 10,000 and 12,000 pounds per square inch. The elastic limit in compression has not been determined by methods as refined as in tension but it apparently occurs at a stress of 25,000 to 40,000 pounds per square inch.

Elastic Modulus

The modulus of elasticity in tension has been found to be between 10,000,000 and 17,000,000 pounds per square inch and in compression between 25,000,000 and 30,000,000 pounds per square inch.

Brinell Hardness

The Brinell hardness varies usually between 220 and 260.

Toughness

When tested on an Izod impact testing machine the specific resistance to impact of ordinary high carbon iron containing 3.72 per cent total carbon and 1.68 per cent silicon was 7 to 8 foot pounds per square inch. The specific resistance to impact of high tensile cast iron determined similarly was 24 to 30 foot pounds per square inch.

Fatigue Limit

Moore and Lyon⁷ found the fatigue limit of low silicon gray iron to be 44 per cent of the tensile strength. Kommers⁸, who investigated plain, alloy and high strength irons, found the fatigue limit to vary between 38 per cent and 57 per cent of the tensile strength. Two series of high strength iron showed a fatigue

⁷ Moore and Lyon, *Tests of Endurance of Gray Cast Iron Under Perfected Stress*. Proc. A. S. T. M., 1927.

⁸ J. B. Kommers, *Static and Fatigue Properties of Some Cast Iron*. Proc. A. S. T. M., 1929.

limit between 43 per cent and 57 per cent of the ultimate strength. Tests in the authors' laboratory showed a fatigue limit of nickel bearing high strength iron to be 56 per cent of the ultimate strength.

Machinability

High strength cast iron is readily machinable. Of course, as the hardness of iron increases the material becomes less readily machinable. The hardness of high strength cast iron being greater than that of high grade cast iron it is slightly harder to machine.

The advantage of nickel in promoting uniform structure and strength throughout heavy sections is also an outstanding characteristic of the use of that element. High strength iron without nickel, having tensile strength in arbitration bars of 40,000 to 49,000 pounds per square inch showed only 7,000 to 30,000 pounds per square inch in the center of three inch rounds. High strength iron of similar composition but containing 2.50 per cent nickel showed tensile strengths between 60,000 and 70,000 pounds per square inch in arbitration bars and 50,000 to 55,000 pounds per square inch in the center of three inch rounds.

Structure

An outstanding characteristic of high strength cast iron is that it possesses a fine grained, uniform, dense fracture. This uniformity throughout castings of uneven section is notable.

Typical examples of the microstructure of high tensile cast iron are shown in Figures 7 to 11.

Fig. 7 is of an unetched specimen magnified 100 diameters. It shows the graphite as extremely fine nodules. This condition is conducive to high strength.

Fig. 8 is the same as the specimen of Fig. 7 but etched and magnified 500 diameters. It shows a fine granular structure unresolved at this magnification.

Fig. 9 is the same as Fig. 7 but etched and magnified 1,000 diameters. It shows the structure barely resolved into extremely fine pearlite. This structure corresponds to high strength. The tensile strength of this material was greater than 62,000 pounds per square inch.

Fig. 10 is another specimen unetched and magnified 100

diameters. It shows fine nodular and very short flake graphite in a test bar accompanying a 12,000 lb. locomotive cylinder. The tensile strength is 61,995 pounds per square inch.

Fig. 11 is the same as Fig. 10 but etched and magnified 500 diameters. It shows a matrix of extremely fine pearlite.

The theory of the mechanics of the process has not been completely solved but it is considered that three factors contribute jointly to the production of high strength.

- (1) Low carbon
- (2) Fine, well distributed graphite
- (3) Strengthening of the matrix by nickel.

Extensive experimental work has demonstrated that, as mentioned before, the range of carbon which corresponds with maximum strength lies between 2.50 per cent and 3.10 per cent. Since this range is considerably below that obtainable by general cupola practice, it is necessary to use charges consisting mainly of steel. Control of the size and distribution of graphite is effected by tapping a white iron from the furnace and then causing the carbon to be precipitated by a graphitizer. There are two aspects of this phase. Silicon acts as a graphitizer by precipitating carbon in very fine evenly distributed particles. The additional graphite refining property of nickel (similar to its action in plain gray iron or semi-steel) augments this effect. Having obtained the graphite in fine, uniformly distributed form it is necessary to pour it into molds before growth into flakes due to coalescence takes place. Here again nickel works to advantage by retarding the rate of graphite growth so that sufficient time can elapse to pour any quantity of metal, according to normal foundry practice, without a detrimental amount of graphite coalescence taking place.

Industrial Applications

Regardless of what the possible properties of a material are, it lacks economic value if it has no industrial application. Following are some examples of the applicability of nickel bearing high strength iron which have proven the practical value of the material.

Cylinders and liners for Diesel engines: Uniformity of structure and hardness are essential in these types of castings because

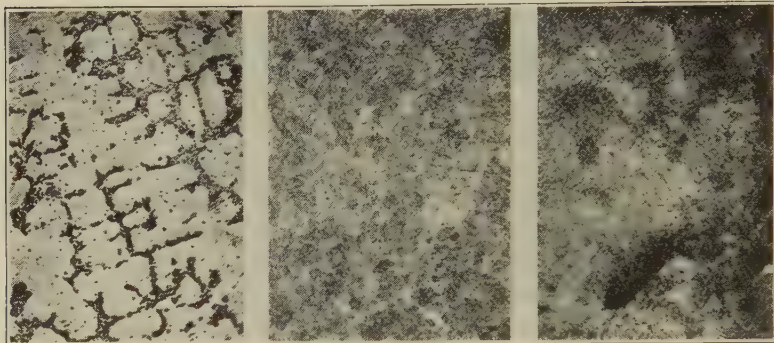


FIG. 7

FIG. 8

FIG. 9

FIG. 7—UNETCHED, MAGNIFIED 100 DIAMETERS, EXTREMELY FINE NODULES OF GRAPHITE IN NODAL DENDRITIC PATTERN.

FIG. 8—ETCHED, MAGNIFIED 500 DIAMETERS. APPARENTLY FINE GRANULAR STRUCTURE UNRESOLVED AT THIS MAGNIFICATION.

FIG. 9—ETCHED, MAGNIFIED 1000 DIAMETERS. GROUND MASS BARELY RESOLVED INTO EXTREMELY FINE PEARLITE.

Total carbon, per cent.....	2.44
Silicon, per cent.....	1.24
Nickel, per cent.....	2.04
Tensile strength, per square inch.....	62,450
Brinell Hardness number.....	180
Microstructure of high strength cast iron test bar.	

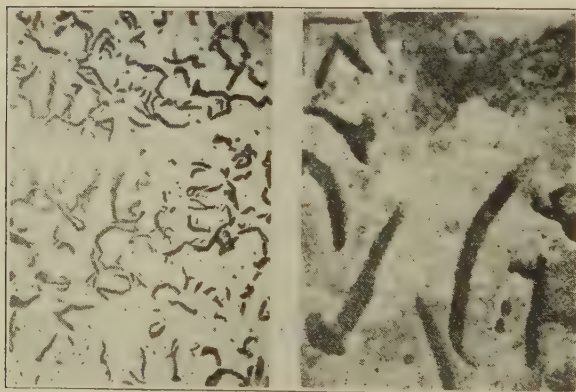


FIG. 10

FIG. 11

FIG. 10—UNETCHED, MAGNIFIED 100 DIAMETERS. FINE NODULES AND SHORT BARS IN DENDRITIC PATTERN.

Total carbon, 2.68%. Silicon, 1.39%. Nickel, 2.14%.

FIG. 11—ETCHED, MAGNIFIED 500 DIAMETERS. FULL PEARLITIC STRUCTURE OF GROUND MASS.

Tensile strength, per square inch, 61,995. Brinell Hardness, 260.
Microstructure of casting weighing 10,000 pounds.

of the requirements of strength and resistance to wear. One manufacturer has found that the combination of high strength with a minimum of 228 and a maximum of 256 Brinell hardness has satisfied the requirements for this type of service. The consistency of these properties and the absence of difficulty during machining have rendered high strength cast iron particularly adaptable to Diesel engine construction.

Gear Casings: Another manufacturer has substituted high strength cast iron for steel castings in the manufacture of gear housings, bases, and frames for miscellaneous machinery. Service records have shown the substitution has been entirely satisfactory.

Crusher Frames: A builder of rock crushing machinery substituted the material described for steel castings and gray iron castings for crusher frames. The high strength iron frames weighed 47,000 pounds, which was 18,000 pounds less than the weight of ordinary gray iron frames.

High Pressure Pumps and Compressors: High strength iron has been successfully substituted for steel castings for use in three stage pumps. It was also found to be satisfactory for CO₂ compressors.

Piston rings: The material described is being used successfully in heavy piston rings. It has been found that the wear on both rings and cylinder walls is less than that of semi-steel. It was also found that these rings retained their shape more permanently and possessed better spring than rings made from plain cast iron or semi-steel.

Hoist drums: Mine hoist drums weighing up to nine tons have been manufactured of high strength cast iron and demonstrated its superiority over steel castings for this purpose, particularly because its rate of wear is less than that of steel.

Gears and Pinions: (a) Rough. Several engineers have expressed the view that for many purposes nickel bearing high strength cast iron is superior to any other type of iron for rough gears and pinions. The strength and hardness at the base of the tooth are almost identical with these properties in the tooth itself. It shows less tendency than cast steel to warp while cooling in the mold. Its superior resistance over other types of iron to resist shock when rough usage is encountered also appeals strongly to engineers.

(b) Machined. In addition to the characteristics enumerated above, the fact that high strength iron gears exhibit less distortion than case hardened gears is a mark of superiority.

Superheated Steam Chambers and Valves: The fact that the material described retains its strength uniformly up to about 1,000 degrees Fahr. is an indication of its superiority over steel castings for these purposes. Its great rigidity when used in valve bodies eliminates leaking after repeated opening and closing.

Forming Dies: Formerly it was found necessary to place tool steel inserts at various places in cast iron dies used for forming sheet steel and boiler plate. High strength cast iron without such inserts has proven to be far superior to other materials for this purpose.

Cams: The variation of accuracy of operations due to wear is vital to the successful operation of Diesel engines, machine tools and many other types of industrial machinery. By increasing the Brinell hardness of high strength cast iron slightly above 300 (it could still be machined) it was entirely satisfactory when substituted for case-hardened or chilled-face cams.

Conclusion

The authors have essayed to demonstrate the strength limitations of plain cast iron and to show how the use of alloys will extend the range of composition in cast iron which will produce maximum strength. They have indicated that the maximum strength obtainable in plain iron was 40,000 to 45,000 pounds per square inch and in alloy iron made by conventional methods 40,000 to 48,000 pounds per square inch. It was pointed out that cast iron with strength well in excess of 50,000 pounds per square inch could be obtained by methods involving heat treatment. Such methods, however, are expensive and involve serious difficulties. The authors have described a comparatively simple and inexpensive method of producing gray machinable castings with a range in tensile strength of between 50,000 and 70,000 pounds per square inch. It was pointed out that the method and product (particularly the nickel bearing product) described furnished a ferrous casting material with properties intermediate between ordinary gray iron and cast steel or malleable iron. Numerous practical applications were also enumerated.

High Test Cast Iron

By O. SMALLEY, NEW YORK, N. Y.

High test cast irons come about from a number of contributory causes. Among these are:

1. The latent and undeveloped possibilities of this "cheapest of alloys" (cast iron).

2. The unreliability of common cast iron under severe service conditions in engineering instruction where close factors of safety are necessary.

3. The necessity of lifting gray cast iron out of the common place and giving to the iron founder an opportunity to confer individually to his product.

4. The need of a weapon of defence and attack against the keen competition of steel castings, forgings and stampings.

Differences of opinion will be found as to which of these is the most important. It will be generally conceded, however, that while a buyer will be willing to pay more for improved or new properties, the ultimate price will reflect what these properties cost in competitive materials.

From the amount of technical publicity devoted to high test cast iron during the past few years, one would imagine that enormous strides had been made and that we were on the verge of a new era of gray cast iron. In actual fact, this is not so. High test cast iron is not new. Its progress has been slow. Most of the so-called "new" processes, although they show what is possible to be obtained from properly made or treated cast iron, have yet to establish themselves practically in the foundry and find their place in the competition of things.

Advances in Cupola Practice

Perhaps the principal advances in cupola cast iron may be summarized as follows:

1. New designs to effect better combustion and superheat the metal.

Discussion of this paper appears on page 729.

2. Use of more steel and scrap iron in the mixes. Also the introduction of alloys.

Despite these, however, the problem of producing consistently good ordinary gray iron castings, uniform in quality, is still with us, and there is yet much to be known about the physical properties. Apart from simple tests like tensile and hardness, we are sadly lacking knowledge of those properties which differentiate one iron from another and which determine their true service-value.

This question of the average founder having problems in making good ordinary commercial castings of known physical attributes is specially mentioned, because if this is true of common gray iron, how much more difficult it is for the average founder to appreciate what is involved in the manufacture of high test cast irons, particularly as there are still many founders today, who do not even recognize the fundamental importance of metallurgical knowledge and supervision.

Methods of Producing High Test Cast Iron

Cupola-melted high test cast iron made under the various processes have the following features in common:

1. Use of high percentage of steel or a lowered silicon content.
2. A lowered total carbon and phosphorus content.
3. Superheating in melting.
4. Control of graphitization by chemical composition or rate of cooling during solidification.

In regards to item 4, the higher the carbon content in gray cast iron, the greater the difficulty in controlling the form of the graphite and the grain matrix, both being equally important in the determination of the physical properties of any casting. On the other hand, the lower the total carbon, the more difficult it is to get uniform softness and homogeneity of structure.

The use of steel in the mix has for its object the control of the quantity of total carbon and to obtain a pearlitic or sorbo-pearlitic matrix. It is to its ability to confer such a structural condition that high steel mixes owe their superior strength, density and hardness. It is for this same reason, however, that

steel is a common cause of hard spots, brittleness and lack of uniform softness.

Superheating in melting is also generally recognized as exerting a similar effect to steel additions in refining the graphite flakes, and in increasing strength through assuring solution of the carbon as carbide rather than as graphite. In the writer's experience, however, these influences are secondary. The primary object of super-heating steel-rich mixes is to obtain the necessary degree of heat to take care of the higher melting temperatures and lower fluidity of such irons and also to insure thorough fluxing and cleansing of the molten iron.

Having obtained the basic condition necessary to the superior physical properties of high test cast iron, viz., a carbide condition of the carbon, there still remains the problem of accurate and uniform decomposition of the carbide during solidification. It is in this respect where most new and patented processes find their application.

Of these processes, a practical, economical and effective method is that of Meehan's using calcium silicide. By introducing pre-determined quantities of this alloy during the filling of the ladle, the carbide balance is disturbed to any desired degree, thus yielding uniform density, grain and softness, and precise control of the physical properties becomes possible.

Photomicrographs of Figs. 1 and 2 illustrate the micro structure of the center of a $1\frac{1}{4}$ -inch section casting containing 2.8 per cent total carbon, 0.6 per cent manganese, 0.1 per cent sulphur, 0.18 per cent phosphorus, and 1.2 per cent silicon.

This iron was melted in the cupola in the ordinary way and consisted of 60 per cent steel scrap, together with cast iron scrap and sufficient high silicon pig iron to give a silicon content of 1.2 to 1.3 per cent. Had this metal been poured direct from the cupola into the molds, the resulting castings would have been uncertain in their test results. The smaller castings would have been white and brittle while the heavier castings would have exhibited chilled edges and maybe cracks, and both the physical properties of machinability would have been uncertain. By the introduction of 120 ounces of calcium silicide in the ladle as the metal filled it, sufficient combined carbon was graphitized so that the finished castings consisted wholly of a matrix of well formed

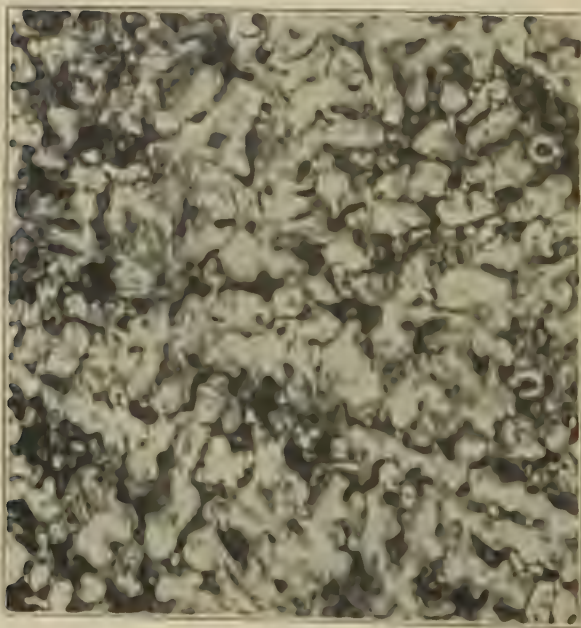


FIG. 1—HIGH TEST CAST IRON WITH TOTAL CARBON 2.80 PER CENT; SILICON 1.20 PER CENT; MANGANESE 0.60 PER CENT; PHOSPHORUS 0.18 PER CENT AND SULPHUR 0.10 PER CENT — AS CAST — MAGNIFIED 100X.

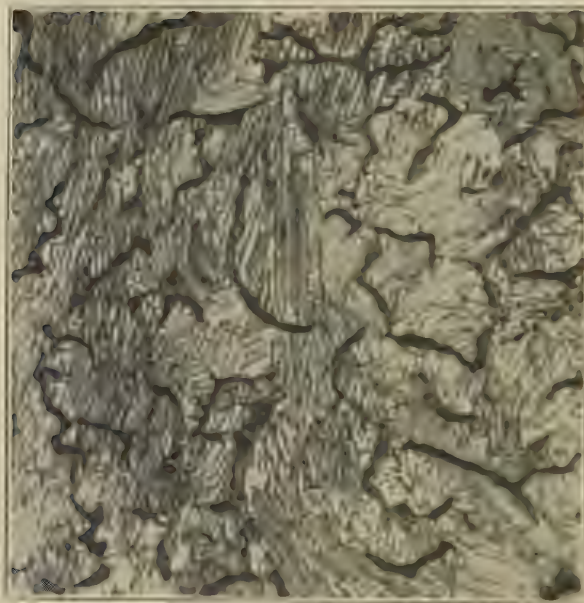


FIG. 2—SAME METAL AS FIG. 1 BUT MAGNIFIED 2000 DIAMETERS

pearlite, while the primary and secondary graphite took a structural formation that affected but little the natural properties of the pearlite. This structural feature explains the high degree of toughness obtained from this casting.

Fig. 1 illustrates this clearly and explains the density and fine fracture that obtains. Fig. 2 shows the inner crystal structure at a magnification of 2,000 times. Both figures reveal the presence of secondary graphite as very fine flakes. These are clearly seen in the central region of Fig. 2 as finer flakes of a lighter tone.

The physical test results obtained from standard test bars were as shown in Table 1.

Table 1

Modulus of Elasticity.....	28,600,000
Ultimate Strength, Pounds Per Square Inch.....	46,700 to 51,000
Elongation, Per Cent.....	0.05 to 1.0
Brinell Hardness Number.....	227-247
Transverse Strength, 1½-inch Diameter Bar Over 12-inch Centers.....	4800 to 4850
Deflection, Inches.....	0.12 to 0.14

In ordinary practice the range of composition permissible varies according to the specific requirements of the castings to be made. Maybe among the most unique features of high steel mixes using calcium silicide is that the silicon content of the iron need not be held within the strict limitations that are necessary to semi-steel mixes. It is, however, important to observe that within certain limits the steel content of the charge going into the cupola must be increased with the silicon content if high test results are required.

Fig. 3 shows the structure of an iron made from a 70 per cent steel mix calculated to give 1.7 per cent silicon. The chemical composition obtained in the finished casting was 2.81 per cent total carbon, 1.65 per cent silicon, 0.8 per cent manganese, 0.115 per cent sulphur, and 0.185 per cent phosphorus.

One hundred ounces of calcium silicide were used per ton of metal in the ladle. The physical test results were as shown in Table 2.

Table 2

Modulus of Elasticity.....	27,800,000
Ultimate Strength, Pounds Per Square Inch.....	46,000
Elongation, Per Cent.....	0.5
Brinell Hardness Number.....	255
Transverse Strength, 1½-inch Diameter Bar Over 12-inch Centers.....	4,300
Deflection, Inches.....	0.16

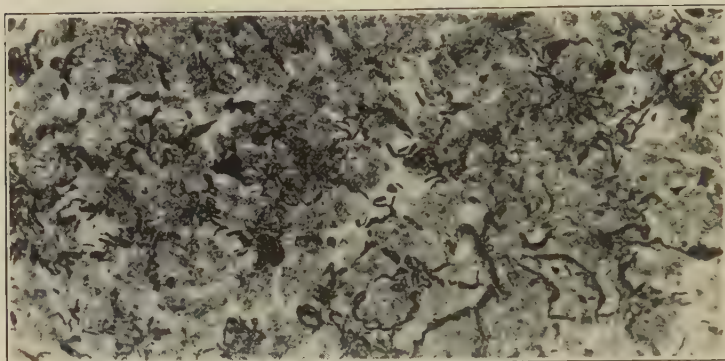


FIG. 3—HIGH TEST CAST IRON WITH TOTAL CARBON 2.81 PER CENT; SILICON 1.65 PER CENT; MANGANESE 0.80 PER CENT; PHOSPHORUS 0.185 PER CENT AND SULPHUR 0.115 PER CENT—AS CAST—MAGNIFIED 100X.

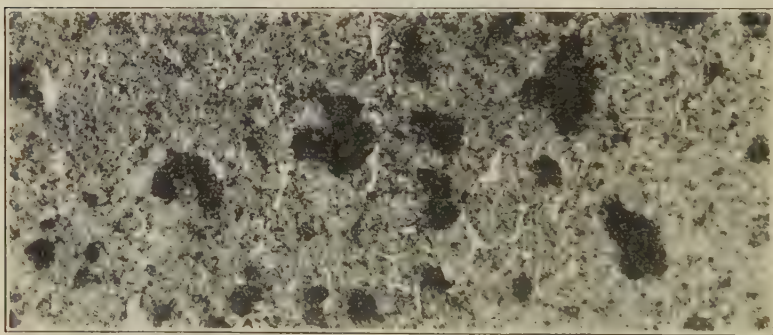


FIG. 4—SAME METAL AS FIG. 3 BUT HEATED TO 1650° FAHR, AND COOLED IN AIR—MAGNIFIED 100X.

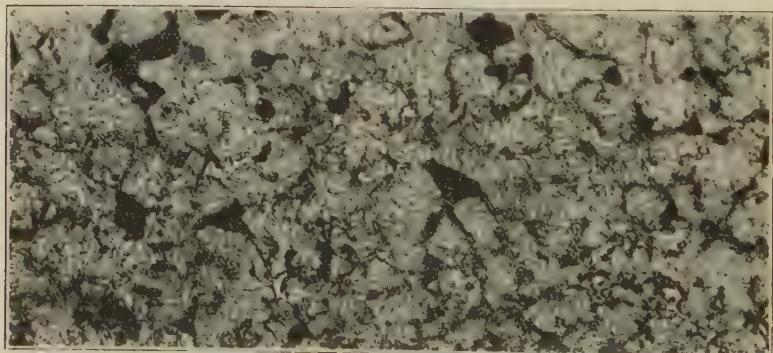


FIG. 5—SAME METAL AS FIG. 3 BUT OIL QUENCHED AT 1600° FAHR, AND DRAWN AT 950° FAHR.—MAGNIFIED 100X.

To measure graphitization in the foundry and control so that a uniform structure and machinability are secured from the metal as it comes from the cupola irrespective of the quantity of steel used in the mix or of the silicon content, the author introduced the calcium silicide by means of a machine and took a chill and wedge test from each ladle of metal before casting. This machine is designed so as to automatically throw the alloy in the stream of metal as it fills the ladle, commencing as the metal is tapped and shutting off when the ladle is full. The quantity is changed by means of a switch operated by the cupola attendant. Each change

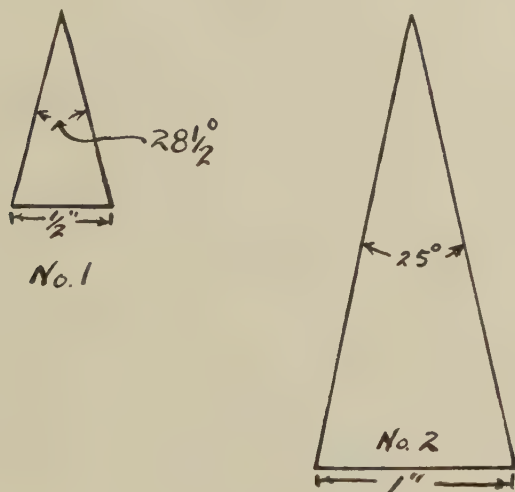


FIG. 6—WEDGE TEST PIECES

has been worked out according to the class of casting to be made and the physical test results required.

The chill test piece is standard. This is run in conjunction with the wedge grain test. This latter is made in baked oil sand mold. For light castings, a wedge of section No. 1 is used. For heavy castings No. 2 is used. The chill test wedges are as shown in Fig. 6.

By noting the fracture of this wedge immediately after casting a quick measure of graphitization is possible from the depth of penetration of whiteness from the knife edge into the heavier section. Thus, if light castings of half inch section down to one-

eight inch sections are to be poured and must be easily machinable, the knife edge must not chill to a depth of more than one-thirty-seconds inches. This standard set and controlled, one may be assured that all the castings made will be entirely free from chilled edges and will machine satisfactorily. Standards are set for castings according to their section, use and test results required.

After experimenting together with long experience with the use of this wedge test bar, it has been possible to correlate the quantity of steel scrap in the mix with the percentage of calcium silicide required to give the desired graphitization to meet any specified test result and machinability.

To any one unacquainted with this development and experienced only in gray iron, this control is difficult to appreciate, but a number of tonnage foundries having established this method of control and their using it daily is proof that this is not merely a theoretical ideal. Actual experimenting by any one interested will convince not only of the high activity and precise control possible by means of a calcium silicide as a graphitizer, but the problem of graphite in cast iron will assume a new aspect.

It is a peculiar fact that little or no calcium is left in the finished iron, while the silicon content increases are negligible and rarely exceed 0.1 per cent, although the calcium silicide alloy used contains 35 per cent calcium and 58 per cent silicon.

Calcium silicide is exothermic in action and develops an intense local heat when it contacts the hot metal in the ladle. Its effect is gaseous; therefore, there is no chance of mechanical contamination.

Heat Treatment

The presence of coarse flakes of graphite and the instability of the carbide of ordinary gray cast irons are responsible for the difficulties and uncertain results obtained by heat treatment or annealing, whether the desired object be to obtain greater strength, hardness, ductility or machinability.

As is well known the matrix of high steel mix cast iron compares with ordinary carbon tool steel; the essential difference between the two being the presence of graphite in varying amounts, depending upon the composition and the quantity of

steel used in the cupola high steel mix. Commencing with a low graphite content and effecting control of its structural form and quantity by the amount of steel charged into the cupola, the temperature of melting and a predetermined calcium silicide addition, the resulting casting presents a base structure that compares with ordinary carbon tool steel, which may be hardened by rapid cooling from above the critical change point and softened by prolonged cooling at or about the Ar point. These changes in the hardening carbide of steel rich mixes obviously affects the physical properties much in the same way as they affect the ordinary 0.9 per cent carbon steel, which consists of a wholly pearlitic structure as indicated by Fig. 2 but with the absence of graphite flakes.

The tensile strength of 0.9 per cent carbon steel with this structure is 108,000 pounds per square inch. If reheated and allowed to cool very slowly in the furnace, the tensile strength falls to 83,000 pounds per square inch, but if it were heated to above the critical change point and allowed to cool in air, the tensile strength would be increased to 132,000 pounds per square inch. Similarly, if quenched in water from above the critical change point, it will be glass hard and Brinell 675, but if it were allowed to cool slowly, a Brinell hardness of 156 would be found.

High steel mixed cast iron is equally susceptible to these conditions of change by heating and cooling. By heating to above the critical change point and quenching, they may be made glass hard, and if cooled slowly, they will Brinell around 156. Similarly is the strength and toughness affected by the rate of cooling.

The influence of heat treatment on the physical properties of a 60 per cent steel mixed iron composed of 2.8 per cent total carbon, 1.20 per cent silicon, 0.6 per cent manganese, 0.1 per cent sulphur, and 0.18 per cent phosphorus, is shown in Table 3.

Table 3

<i>Treatment</i> —Heat to 1650 Degrees Fahr., Two Hours Cooled in Air.	
Modulus of Elasticity.....	29,200,000
Ultimate Strength, Pounds Per Square Inch.....	95,000
Elongation, Per Cent.....	Nil
Brinell Hardness Number.....	241
Transverse Strength	6,500
Deflection, Inches	0.31

The technique of manufacture of high steel mix irons responsive to heat treatment to yield such high test results is somewhat involved, for apart from the difficulty of melting high steel mixtures, graphitization must be conducted with considerable care and carried out to such a stage that heating for the purpose of hardening does not decompose any of the hardening carbide.

The micro structure obtained after the above normalizing treatment is shown by Figure No. 4.

By again changing the degree of graphitization and depending upon heat treatment to completely dissociate the remaining carbide and allowed to cool slowly from between the temperatures of 1,550 degrees Fahr. and 1,200 degrees Fahr., the physical properties shown in Table 4 were obtained from this iron.

Table 4

Treatment—Annealed Twenty Hours, 1600 Degrees Fahr., Cooled in Furnace.

Modulus of Elasticity.....	24,400,000
Ultimate Strength, Pounds Per Square Inch.....	48,000
Elongation, Per Cent.....	5½
Brinell Hardness Number.....	140
Transverse Strength.....	4,500
Deflection, Inches.....	0.78

Mass Effect

To show the uniformity of section of the above material when cast in large masses, tensile tests were taken from the center and edge of a 6-inch section with the following results: outside, 46,000 pounds per square inch, and center, 43,600 pounds per square inch.

High Test Cast Iron

BY R. S. MACPHERRAN,* MILWAUKEE, WIS.

In discussing the subject of high test cast iron we would like to make it clear that we are giving our own practice *only* and in no way criticizing others who may prefer different details of operation. We will also refrain from going into the theory of the structure or composition, as these have just been explained to you by others.

Our method of operation is very simple. We use a 54-inch cupola with one row of tuyeres, six in number, and a blast pressure of 8-ounces. These tuyeres are $3\frac{1}{2}$ inches by 26 inches in size and are 19 inches above the sand bottom. The bed is 2,300 pounds of coke. After charging the cupola it is allowed to stand about one hour before the blast is put on.

Our metal charges are of 3,000 pounds weight, with 375 to 400 pounds of coke between charges. This charge consists of about 95 per cent steel scrap with $4\frac{1}{2}$ per cent of ferro-silicon and $\frac{1}{2}$ per cent of ferro-manganese. The ferro-silicon contains 50 per cent of silicon. We have also used about 15 per cent of a low-grade ferro-silicon containing 15 per cent silicon with about 85 per cent steel. This works very well, but does not give quite as low carbon as the higher grade silicon with the greater per cent of steel in the mixture.

The steel is about one-half to two-thirds railway car springs and the remainder is steel rails. We have been advised to make short taps, as this tends to keep the carbon down. We pour from each ladle a standard arbitration test bar. From the lower half of this test bar we cut a 0.505-inch diameter tensile bar with threaded ends.

We have made a list of 63 test bars, together with their tensile tests and chemical analyses. These have not been selected and are in no way experimental, but have been taken consecutively from

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Discussion of this paper appears on page 729.



FIG. 1—STRUCTURE OF HIGH TEST CAST IRON—100X UNETCHED—BAR BROKE AT 71,400 POUNDS TENSILE STRENGTH AND HAD A BRINELL HARDNESS NUMBER OF 269.

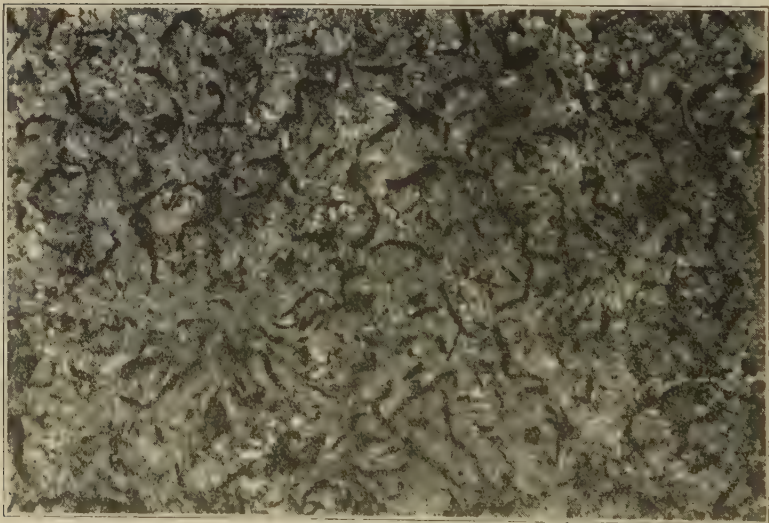


FIG. 2—SAME IRON AS FIG. 1—100X ETCHED.



FIG. 3—SAME IRON AS FIG. 1—1000X ETCHED.

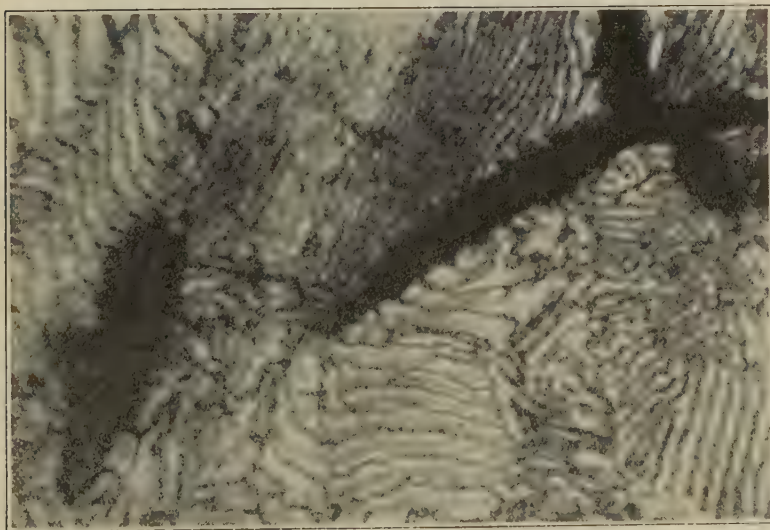


FIG. 4—SAME IRON AS FIG. 1—3000X ETCHED.

last October, good, bad and indifferent. Each ladle represents not less than 2,000 pounds or over 17,000 pounds of metal. Of these 63 bars we found:

5 breaking between 47900 to 50000 pounds tensile strength per square inch
37 breaking between 50000 to 60000 pounds tensile strength per square inch
19 breaking between 60000 to 70000 pounds tensile strength per square inch
2 breaking over 70000 pounds tensile strength per square inch

The general average is 58,300 pounds. None of these bars was heat treated in any way.

We generally use 1 per cent nickel, either melted in the cupola or added to the ladle. When added to the ladle we invariably preheat to a dull red. In the spout we usually add about 6 pounds per ton of a ferro-manganese-silicon containing about 50 per cent silicon and 25 per cent manganese. Wherever possible, however, we prefer to melt our iron and alloys in the cupola and not in the ladle. We realize that in theory it is better to add ferro-silicon, etc., to the ladle. Although this may give a higher strength in the bar we believe it has the danger of cooling the iron too greatly and therefore maintain our present practice.

When making our first heats of this material we rather expected that the metal containing so much steel would come out cold. The exact contrary is the result. The iron is hotter than any iron we have ever made. It has, however, a short freezing range and should be handled quickly.

We also expected to find a large amount of liquid shrinkage, together with considerable solid contraction. While there may be a little more solid contraction than with a weaker iron we do not find any increase in the liquid shrinkage. It does, however, need a rather better grade of sand, as the pouring temperature is usually quite high. It does very well in dry sand molds. It is considerably harder than the usual run of cast iron and, in fact, machines about like a steel casting. In order to overcome any possible difference in fluidity we have made our gates and risers a trifle larger than for ordinary iron.

We would again point out that the above are not research or experimental tests. Every ladle quoted was used to make castings for a shipping order.

The total carbon runs from 2.40 to 3.10 per cent, silicon from 1.60 to 2.60 per cent, manganese, preferably 0.70 to 0.90 per cent. The Brinell hardness on the test bar runs from 240 to 290. The

Brinell on the casting will vary somewhat and will be lower on a large casting. In general, however, it will run about 225.

The high carbons usually come from a small ladle run first from the cupola. The secret of high test iron seems to be low carbon and high temperature of melting. We have varied the silicon from 1.50 to 3.00 per cent without materially affecting the strength of the test bar. The above is not claimed to be the

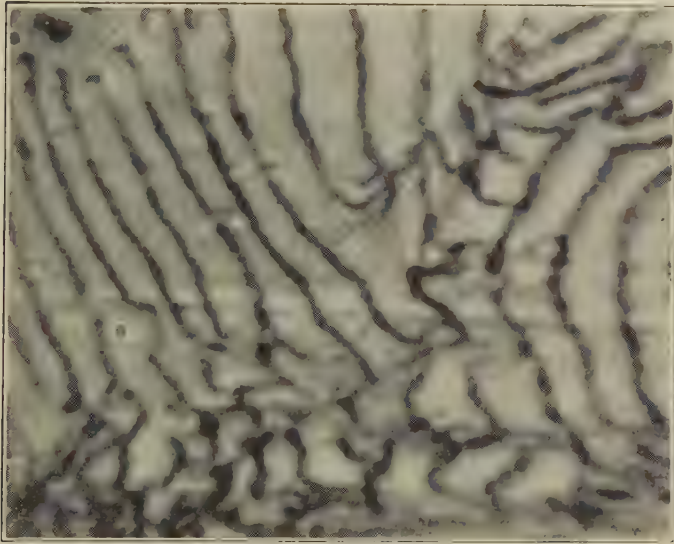


FIG. 5—SAME IRON AS FIG. 1—5000X ETCHED.

ideal practice, but is producing castings commercially of high strength.

It is quite possible that if we were able to standardize the amount we melt, reduce our coke and could always have a 5 to 6-ton ladle to run first we would be able to get more consistent results. We could also get a lower carbon in small heats by using a smaller cupola.

The variations above referred to are due to at least three causes. First, low melting point of ferro-silicon, which sometimes runs ahead. Second, small size of some ladles (2,000 pounds).

Third, for special reasons some of our large castings purposely are made with silicon below 1.80 per cent.

We have here a few micrographs taken of a test bar poured from a 4-ton ladle, second from cupola, which broke at 71,400 pounds, with a Brinell of 269. The analysis of this bar was:

Total carbon	2.81
Silicon	2.12
Sulphur	.097
Manganese	.94
Nickel	1.13
Graphite	2.01
Combined Carbon	.80

We wish, in closing, to recognize the cordial cooperation of our foundry superintendent, A. E. Harrison, and of our other foundry foremen as well as the excellent work of Rexford Krueger in preparing these photomicrographs.

The Refractoriness of Molding Sands*

By J. F. McMAHON,** OTTAWA, CANADA

In June, 1924, the Joint Committee on Molding Sand Research of the American Foundrymen's Association issued a report in bulletin form which contained tentatively adopted methods of tests for molding sands as formulated by the Sub-Committee on Testing Methods.¹ At the time of this publication no concerted attempt had been made to formulate a test for the refractoriness of molding sands. In October, 1924, it was decided that this important subject should be investigated, and at the request of the Sub-Committee on Testing Methods, Cornell University, Ithaca, N. Y.; the Bureau of Mines, Columbus, Ohio, and the Mines Branch of the Department of Mines at Ottawa, Canada, agreed to make a study of the refractoriness of molding sands, and, if possible, to formulate a test for its determination. The investigators at these three institutions worked independently, making occasional reports to the sub-committee.

In the transactions of the American Foundrymen's Association (Vol. XXXIV, 1926), are found, Dr. D. W. Traynor, Jr.'s, report of the work done at Cornell University, K. E. Buck's report of the work done at the Bureau of Mines, Columbus, Ohio, and H. Fréchette's resume of the work done at the Mines Branch, Ottawa, Canada.

Coincidental with the above investigations, the U. S. Bureau of Standards had been studying the refractoriness of molding sands, and C. M. Saeger, Jr., had devised a very promising method of tests which he kindly communicated to the committee. This method was fully described in a circular letter of the Bureau of Standards, dated April 24, 1928, and has since been adopted by the A. F. A. as one of the tentative standard methods.²

*Contributed with the permission of the Director, Mines Branch, Dept. of Mines, Ottawa, Canada.

**Ceramic Engineer, Mines Branch, Dept. of Mines, Ottawa, Canada.

¹ Transactions, American Foundrymen's Association, Vol. 31, pp. 683-749 (1924).

² *Standard and Tentatively Adopted Methods of Testing and Grading Foundry Sands*, A. F. A. publication, July, 1928, pp. 76-79.

Discussion of this paper appears on page 571.

This present paper covers the work as carried on in the laboratories of the Mines Branch of the Department of Mines, Ottawa, Canada, as presented in the 1926 Report of the Ceramics and Road Materials Division, together with a synopsis of the writings of previous investigators, and is here presented so as to make the data more readily available to the foundry industry.

Definition

The degree of refractoriness of a material is generally defined as a measure of the ability of that material to withstand heat. However, since the conditions under which the heat is applied have a marked effect upon the temperature at which certain heat reactions take place, it is necessary to consider the prevailing conditions in service, when studying the refractoriness of a material. More specifically, refractoriness has come to mean the ability of a material to withstand heat under definite conditions, such as atmosphere (oxidizing, neutral, reducing); slag action (acid, neutral, basic); heat application (sudden, gradual); and load (heavy, light).

In linking up refractoriness with a material for a specific type of service, the conditions under which the heat is applied and the characteristic change of state evidencing failure for that service must be recognized.

A molding sand made up into a desired shape stands on the foundry floor at a temperature perhaps a little above that of the atmosphere. Then from the ladle to the sand is poured molten metal, the temperature of which varies up to 1,670 degrees Cent. The conditions which prevail at the point of contact of the sand and molten metals are:

1. Atmosphere—highly reducing.
2. Slag action—slight.
3. Heat application—sudden.
4. Imposed load—pounds to tons per square foot.
5. Temperature—up to 1,670 degrees Cent.

Therefore, it may be stated that the refractoriness of a molding sand is the degree to which that sand will withstand heat with the prevailing conditions of reduction, thermal shock, and an imposed load, without any detrimental chemical or phys-

ical changes. The characteristic detrimental change may be regarded as that which causes the sand to fuse to the casting.

Heat Reactions

The reactions that may be expected when a molding sand is heated to increasing temperatures are as follows:

The removal of mechanically-held and chemically-combined waters. These waters are all removed at temperatures below 500 degrees Cent.

The breaking down of the carbonates. At temperatures up to 900 degrees Cent. the carbonates of magnesium, calcium and iron break down, giving off CO_2 to form the oxides.

Shrinkage of the bond. The temperatures at which bonds begin their shrinkage vary according to their natures. This amounts to a sintering and knitting together of the fine particles and occurs usually from 1000 degrees Cent. upwards. In this reaction the bond tends to pull away from the non-shrinking sand grain.

Vitrification of the bond. Upon the further application of heat, the bond approaches a liquid phase and as such reacts very readily with its impurities to develop a more stable compound, or mixture of stable compounds, depending upon the impurities and the percentages of same present. All the substances present in the bond, being in such a finely divided state, react very rapidly at this stage. The resulting products vary, not only in composition but also in viscosity. In certain instances the flow begins at the formation temperature, while in other instances flow does not begin until the temperature has advanced much higher. Between these two limits, there are varying degrees of viscosity.

Corrosion of accessory minerals. The condition of the bond at the previous state promotes its reaction with the materials in the sand, such as feldspars, mica, etc. At temperatures producing this reaction, the impurities just mentioned are very active themselves and unite easily with the slag to form various eutectics.

Corrosion of sand grains. The sand grains, being of such a stable nature (silica) and being so large grained (in comparison

to the rest of the matter), are the last to be demolished. By continued heating these sand grains are gradually absorbed by the slag and enter into the liquid phase.

FACTORS AFFECTING THE REFRACTORINESS OF A MOLDING SAND

The Mineral and Chemical Constituents of the Sand

This is the factor of primary importance in that upon it depends the reactions that take place in the sand upon the application of heat.

Table 1, based on Boswell's list³ of thirty-one molding sands which he gives as being in use in the industry, shows the wide range of chemical composition together with comments.

Table 1

Substance	Per Cent	Comments
SiO ₂	95.86 to 46.67	Very refractory and stable. Mostly in the form of quartz. Some in clay, feldspar and mica.
Al ₂ O ₃	24.81 to 2.03	In clay and feldspar. Very refractory in itself.
Fe ₂ O ₃	5.47 to 0.13	Found coating the grains of quartz. In the clay and concretionary. Refractory in itself. Easily reduced.
FeO	0.56 to 0.15	Found in various minerals. Not refractory. Fluxes easily with silica and alumina.
MgO	1.78 to 0.16	Found mostly in mica and in clay substance. Refractory in itself but undesirable due to its basic properties.
CaO	4.55 to 0.14	Found as carbonate and in feldspar and clay. Refractory in itself but an active flux when heated with SiO ₂ and Al ₂ O ₃ .
Na ₂ O	1.50 to 0.06	Found in clay. Flux, not refractory.
K ₂ O	5.45 to 0.50	Found in clay but mostly in feldspars. Active flux, not refractory.
Ign. Loss	12.29 to 0.47	Carbon dioxide. Carbonaceous matter, aids in reduction.
H ₂ O	3.18 to 0.56	Not important as far as refractoriness is concerned.
H ₂ O	2.11 to 0.28	
CO ₂	3.52 to None	
TiO ₂	0.97 to 0.06	Found in magnesium and calcium carbonates. Has no effect upon refractoriness.
ZrO ₂	Trace to None	Found in clay matter and ilmenite. Negligible.
P ₂ O ₅	0.15 to None	Unimportant as far as refractoriness is concerned.
SO ₃	0.42 to None	
Cl ₂	0.03 to None	
MnO ₂	0.06 to Trace	
BaO	0.04 to None	

The chemical analyses that are possible within the above limits give an idea of the great diversity in the chemical and mineralogical compositions of various sands used in the industry. While the chemical analyses are very important, they do not give an index to the refractory value of the sand because of the various mixtures of minerals that are possible within such limits as noted above. Once a sand has been tested for refractoriness, chemical analysis should be an ideal guide to its constancy.

³Moulding Sands for Non-Ferrous Foundry Work, P. G. H. Boswell.

Composition of Molding Sand

Molding sand consists of two component parts, granular material and clay substance.

Granular Material. This consists principally of quartz grains which are very refractory. Mingled with the quartz grains may be many minerals, the most common of which are feldspar, magnetite, garnet, mica, and calcite. These represent that part of the granular material which, due to ease of fusibility, ease of reduction, or fluxing action, fails first under heat. However, their effect upon the quartz grains is usually small because of the small amounts present and the restricted surface contact. In a sand the granular portion is usually the more refractory portion.

Clay Substance. The clay substance of a sand is the weak factor in the refractoriness because it usually carries with it most of the fluxing elements in a very finely divided and intimately mixed state. The more important item in this consideration is the refractoriness or quality of the clay substance. The quality varies in different sands and only when it is nearly the same in the sands under consideration does the quantity become important. The tests made in our laboratories show the importance of the clay substance and the part which it plays in refractoriness. The clay substance alone might be used for a refractoriness determination of the sand within broad limits.

Fineness of Grain

Fineness of grain affects the refractoriness of a material inasmuch as upon it depends the surface contact and hence the ease of chemical reaction.

Early Investigations

Although the property of refractoriness is of decided importance, in view of the high temperatures to which molding sands are subjected, very little investigational work has been done in the past and no standard method of determining it has been adopted.

C. P. Karr in a paper "A preliminary report on molding sands"⁴ states as follows:

"The refractoriness of a molding sand may be shown by

⁴ Trans. American Foundrymen's Association, Vol. 24, pp. 150-151 (1916).

its melting point. The method used for determination of its melting point follows:

"Carefully mixed moist samples of the different sands were compressed without grinding into small compact cylinders and melted in an Arsen Graphite Resisting Vacuum Furnace. The sample to be melted was placed in a porcelain crucible on a bed of fused alumina, and the crucible was placed within a long porcelain tube to protect the sample from the vapor of carbon. The temperature was raised slowly enough to observe within a five-degree range, and watched constantly through a glass window in the top of the furnace. The melting point was taken as the temperature at which the cylindrical sample began to settle and bulge, flowing perceptibly. Corners were rounded at considerably below this point which, nevertheless, is the most definite and useful point to consider as the melting point. The temperatures were measured with a Holburn Kurlbaum optical pyrometer. The pyrometer was sighted through the glass window and arranged to swing away while observing the sample. The current of electricity through the pyrometer lamps was measured to an accuracy of .001 amperes corresponding to 2 degrees Cent. The furnace heating current was switched off not more than from 10 to 15 seconds after the observed melting point, the temperature of the sample rising no more than 5 degrees Cent. above that point. After removing, the cylinders were found to be well fused and only slightly changed in shape."

Curtiss, in his "Steel molding sands and their behavior under high temperatures"⁵ outlines a method as follows:

"Unfortunately, the firing of small test pieces of steel molding sands in the electric muffle or other type of furnace at high temperatures does not give all the required information, as, after firing, such test pieces become too friable for microscopical examination, or other surfaces too distorted, to form any accurate view of how the face of such test pieces (analogous to the face of the mold) withstand the action of the temperature used. For the purpose of this research, refractory tests were carried out by means of a fixed oxygen blow pipe flame, under which the test pieces were travelled in a horizontal plane. As it was considered desirable to employ a wide range of temperatures, for the

⁵*Carnegie Scholarship Memoirs*, 1925. Iron and Steel Institute.

refractory tests, in order to avoid errors in temperature and accidents due to test pieces becoming damaged in operation, a range of from 1200 to 1790 degrees Cent. (Seger cones 6a, 10, 14, 18, 27, 32 and 36) in units of 100 degrees Cent. were adopted. Standard test pieces 1 inch by three-quarters inch by one-quarter inch were used and means were provided for examining microscopically all test pieces during exposure to the varying temperatures employed. Seger cones ground up and reformed in rectangular fireclay troughs of the approximate sizes (1-3/16 inch by seven-eighths inch by one-quarter inch) were used as temperature indicators. The period of exposure to each successive heat, when taking photomicrographs, obviously varied, and different exposures were used for widely differing materials."

In various sections of his article, the following may be found:

"It might be stated that, in the author's opinion, the value of the ultimate chemical analysis cannot be overestimated for checking the stability of either steel molders composition, natural argillaceous steel molding sands, artificial steel molding sands, or proprietary mixtures, together with clays and silica sands which often form the basis of artificial facing mixtures.

"A survey of the analyses of commercial clays having high refractory qualities will seldom find a material classified as a clay with an alumina content of less than 10 per cent.

"The uniformity of grain will confer high permeability and high refractoriness.

"The presence of carbonaceous matter tends to reduce the fusion. The flux content should not be over 4.84 per cent."

Curtiss also makes comparison of results of fusion with chemical analyses throughout, and considers the flux content the controlling factor of same.

Boswell⁶ in his article, "Moulding sands for non-ferrous foundry work," says that "ferrous compounds tend to fuse rather readily, but certain ferric compounds, particularly the oxides, are highly refractory, if the conditions (as always, in molding sand practice) are *oxidizing and not reducing*. As an example, it may be mentioned that the bond of the most successful steel molding sand is largely hydrated ferric oxide."

⁶*British and American Foundry Practice, with Special Reference to the Use of Refractory Sands*, P. G. H. Boswell.

"Feldspar is undesirable for high temperature work, due to low fusion, and desirable in low temperature work, due to bonding powers."

Boswell gives the chemical analyses of 31 sands used as molding sands. Their limits were given as in Table 2.

Table 2

Substance	Per Cent	Substance	Per Cent
SiO ₂	95.86 to 46.67	H ₂ O	2.11 to 0.28
Al ₂ O ₃	24.81 to 2.03	CO ₂	3.52 to None
Fe ₂ O ₃	5.47 to 0.13	TiO ₂	0.97 to 0.06
FeO	0.56 to 0.15	ZrO ₂	Trace to None
MgO	1.78 to 0.16	P ₂ O ₅	0.15 to None
CaO	4.55 to 0.14	SO ₃	0.42 to None
Na ₂ O	1.50 to 0.06	Cl ₂	0.03 to None
K ₂ O	5.45 to 0.50	MnO ₂	0.06 to Trace
Loss on ignition	12.29 to 0.47	BaO	0.04 to None
H ₂ O+	3.18 to 0.56		

"Good steel molding sands should not have alkali content over 1.00 per cent. Best have .5 to .7 total alkali.

"Lime and magnesia should amount only to .5 per cent to .6 per cent with magnesia on the greater end.

"Very few carbonates are present. Lime is probably combined with soda and alumina or silica—sometimes found that was exactly the amount needed for labradorite.

"Magnesia probably with mica.

"Titanium increases in the clay grade. Forms 5 per cent of clay substance.

"Six to seven per cent Fe₂O₃ causes fluxing action and formation of silicates of iron.

"Best sands carry over 2 per cent and sometimes as high as 5 per cent iron oxide."

R. Moldenke⁷ says: "A good sand should resist high temperatures and be friable after use as a mold, be of such a texture that the surface of the casting is small and free from blemishes.

"A low percentage of feldspars is desirable owing to their ready fusibility."

Laboratory Methods

While the specific refractoriness (that is the temperature at which the sand would fail under foundry conditions) could be determined by preparing molds of the sand and pouring into them molten metal at increasingly higher temperatures until that at

⁷*Mechanical World*, Vol. LVI, p. 248.

which the sand would sinter to the surface of the casting was reached, it would be a very expensive procedure and practically impossible to perform on a small scale in a laboratory.

The methods that suggested themselves do not measure the specific refractoriness of the sands, since they do not reproduce the service conditions in every respect, but they have been tried out in the Mines Branch laboratories on a series of seventeen samples of commercial foundry sands to learn whether they might be useful in determining the relative refractoriness of such sands.

These tests are as follows:

1. Softening point determination, entire sand.
2. Softening point determination, clay substance.
3. Sag test.
4. Draw trial.
5. Local application of heat (Saeger's test).
6. Fineness.

Softening Point Determination, Entire Sand

This method was chosen first because of its general use in the testing of refractoriness of materials which are similar to molding sands. This test is one that is in every-day use in the ceramic industry for the testing of the refractoriness of the clays, etc., which are used in that industry.

Preparation of Sample. The material was quartered down to a 200-gram sample. This sample was then ground in an agate mortar to pass a 60-mesh screen.

The material was then moistened sufficiently to allow it to be made into "cones" similar to standard pyrometric cones (tetrahedra 7 millimeters along the edges of the base and 30 millimeters high). They were molded by hand in a steel mold. In the case of nonbonded sands (4, 5, 7, 8 and 14) sufficient gum tragacanth was added to furnish the necessary bond.

The cones when dry were embedded in a plaque of alundum to the depth of 2 millimeters alternately about the periphery of the plaque with standard cones of successive numbers. The angle between the face of the cone and the plaque was approximately 75 degrees. The standard cones used were those of the Seger

formulae as manufactured by the Standard Pyrometric Cone Co., Columbus, Ohio.

The furnace was a carbon-resistance furnace which was capable of temperatures up to 1800 degrees Cent. Strong reducing conditions were present. The temperature was raised to 1000 degrees Cent. in one hour, and thereafter at the rate of 60 degrees per hour.

The softening point taken was that point at which the sand cone tipped and touched the plaque. The results of the test (Table 3) are given in standard cones with their accepted corresponding temperatures.

Table 3

Sand Number	Softening Point, Cone No.	Softening Point, Degrees Cent.
1	14½	1420
2	16	1450
3	17½	1480
4	32½	1713
5	32	1705
6	14	1410
7	33½	1730
8	32	1705
9	26	1600
10	26	1600
11	26	1600
12	15	1430
13	20	1530
14	34	1740
15	15	1430
16	17	1470
17	14½	1420

The above test is one which gives the ultimate heat-resisting qualities of the material. Undoubtedly its use would be of value in determining the refractoriness of a molding sand. However, its results represent reactions which have gone to completion rather than the beginning of such reactions. It appears that in molding sands, the desired factor is the beginning of failure rather than complete failure. A further discussion of the softening point test is given under the test of clay substance in the molding sand.

Softening Point Determination, Clay Substance

Considerable stress has been laid, and justly so, upon the importance of the clay bond in the determination of the refractoriness of a molding sand. In order to ascertain the degree to which the component of the sand affected its refractoriness the following experiments were run.

Washing. The clays were washed free from the sand grains by the method suggested in the fineness tests of the A. F. A. standard tests.⁸

The only deviation from this standard was the use of ammonium hydroxide in place of the sodium hydroxide as specified. This was done in order to avoid any fluxing action which the sodium would impart to the clay.

Preparation of Test Pieces. The clay bonds were made into cones and tested in a similar manner to the entire sands.

The results obtained by this test were those given in Table 4.

Table 4

Clay Substance Number	Cone No.	Temperature Degrees Cent.
1	10	1330
2	1	1150
3	03+	1099
6	10	1330
9	28	1635
10	14	1410
11	27	1620
12	16	1450
13	8	1290
15	10	1330
16	03+	1099
17	9	1310

Sag Test

This test was carried on to determine at what temperature bending would take place in a bar of molding sand, 4 by 1 by one-half inches, when resting on the flat upon two supports 3 inches apart. See Fig. 1.

Preparation of Sample. The sand was quartered down to a 500-gram sample. The sample was then passed through a 16-mesh screen and tempered with sufficient water to allow molding. The oversize was rejected in this test.

Test Bars. In making the bars, the tempered sand was carefully fed through an elliptical funnel into a steel mold, 4 inches long, $1\frac{1}{3}$ inches deep and one-half inch wide. The sand was then consolidated by three blows centered on a wooden rammer, with the drop weight of the A. F. A. permeability apparatus. Sufficient sand was used to produce a finished bar 1 inch in width.

Furnaces. At the outset, these tests were run in a small, gas-fired, low air pressure Palo furnace; two tests being run at the same time. The results were very unsatisfactory. The sag bars

⁸American Foundrymen's Association Tentatively Adopted Methods of Test, June 14, 1924.

in the second instance were burned in a gas-fired kiln of small dimensions and later put into the Palo furnace, the former kiln serving to preburn the pieces and the latter furnace to produce the sag. This also proved unsatisfactory due to the lack of strength in the preburned pieces. For the final test a kiln large enough to take care of all pieces at once was used. This was a gas-fired, down-draught kiln provided with a muffle.

Rate of Heating. This factor is probably the most important item to be contended with in running sag tests. The difficulty of maintaining a regular and definite rate of heating was the chief reason why the small Palo furnace was useless in this test. To overcome this difficulty, the Palo furnace was heated and held at 1000 degrees Cent. until the pieces which had been burned in the above-mentioned gas kiln to that temperature were inserted upon their supports. This proved unsatisfactory. The rate chosen and used in the operation of the large kiln was 100 degrees per hour up to 1000 degrees Cent. and thereafter at 35 degrees per hour.

The results of the sag test run in the large down-draught, gas-fired kiln are given in Table 5, as determined by an optical pyrometer.

Table 5

Sand Number	Water, Per Cent	Weight, Grams	Temp. Sag, Degrees Cent.
1	15	72	1167
2	10.2	72	1417
3	6.8	60	1150
4 Too fragile to test.....	....	..	....
5 Too fragile to test.....	....	..	....
6	10.8	60	1220
7 Too fragile to test.....	....	..	....
8 Too fragile to test.....	....	..	....
9	12	72	1420+
10	10	60	1420+
11	9.8	60	1420+
12	10.4	70	1130
13	14.6	65	1205
14 Too fragile to test.....	....	..	....
15	13.2	65	1215
16	10	65	1220
17	8.8	65	1250

The above test is one that is easily duplicated and lends itself to the problem at hand. This test comes a little closer to giving the initial point of failure, than does the softening point determination. This, of course, was to be expected since the effective bending moment was much greater and, therefore, less softening was required to cause distortion. The results of the sag

tests are lower than the softening points because the reactions had not progressed to the same extent by the time the index point had been reached. This method is not suitable for low bonded sands.

Draw-Trial Tests

The purpose of this test was to determine whether it would be practical to determine the refractoriness of molding sand by noting the effect of different temperatures upon the burned strengths and other properties of the sand.

Preparation of Sample. The sand was quartered down to a 1000-gram sample, passing through a No. 16-mesh screen, and tempered with sufficient water to allow molding.

Test Pieces. The sand was then carefully poured through a funnel into a steel mold, which was shaped to produce a hollowed cylinder $1\frac{1}{4}$ inches in diameter with a three-eighths inch hollowed center. Sufficient sand was used to produce a finished cylinder 1 inch in height. The sand was then rammed with three blows of the drop weight of the A. F. A. permeability apparatus on a steel rammer. The pieces were then allowed to dry slowly.

Furnace. The furnace used for this test was the large gas furnace used in the sag tests.

Rate of Heating. The temperature was raised to 600 degrees Cent. at the rate of 100 degrees per hour, and thereafter at 30 degrees per hour.

Procedure. The test pieces were placed upon fireclay trays, those to be drawn at the same temperature being placed on the same tray.

When predetermined temperatures, commencing at 1010 degrees Cent., were reached the furnace was opened and a tray

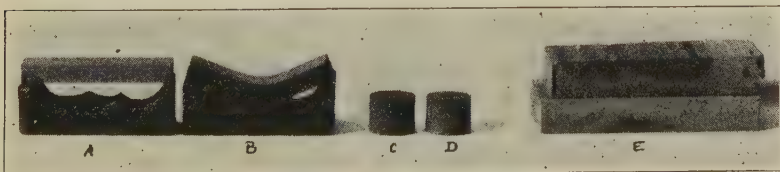


FIG. 1—(A) SAG TEST BAR (BEFORE BURNING); (B) SAG TEST BAR (AFTER BURNING); (C) DRAW TRIAL PIECE (BEFORE BURNING); (D) DRAW TRIAL PIECE (AFTER BURNING); (E) BAR AFTER RUNNING SAEGER TEST

of test pieces was removed quickly to another muffle furnace which was maintained at a constant temperature of 900 degrees Cent. When all the test pieces had thus been transferred to the second furnace, it was allowed to cool slowly.

The test pieces, after slow cooling, were subjected to crushing tests on an Olsen machine. Before breaking and again after breaking they were examined under a microscope and the observations recorded.

For the purpose of recording the observations under the microscope, the following terms were chosen indicative of the effect produced by the heat.

1. Little effect.
2. Bond shrunk (which signifies the shrinking of the bond away from the sand grain).
3. Bond vitrified (the formation of the bond into vitreous (not fluid) material).
4. Little glass (the beginning of flow of bond and corrosion of grains).
5. Considerable glass.
6. Much glass.
7. Bond fusion progressed far (all bond in a glassy state).
8. Few grains fused (melted independently of corrosion).
9. Many grains fused (partial fluxing of the sand grain).
10. Fused (complete fluxing of sand grains by the glassy bond).

The results of the tests are given in Table 6.

The figures given for strength in Table 6 are important inasmuch as they link well with the observation under the microscope. Together they show the temperature at which the sands fail. It is not considered important that in sand No. 1, the cone 02 burn has greater strength than the cone 1 burn, because the differences are too small to suggest any particular change. However, in the same instance, when the strength of the cone 1 burn differs so greatly from the strength of the cone 4 burn, it suggests a radical change in the condition of the material. Between cone 1 and cone 4, this sand has undergone a change, and that change as seen by the microscope was the formation of much glass as a matrix to the sand grains. This is the point at which the sand fails. Figuring likewise from the figures on all the

Table 6

RESULTS OF DRAW-TRIAL TEST

Sand No.	Cone No.	Temp., Degrees Cent.	Strength, Load in Pounds	Microscopic Observation	Remarks
1	07	1010	No load	Bond shrunk	
1	05	1050	61	Bond vitrified	
1	02	1110	275	Very little glass	
1	1	1150	178	Considerable glass	Grains fused
1	4	1210	1264	Much glass	" "
1	6	1250	3100	Much glass	" "
1	9	1310	4700	Much glass	" "
1	11	1350	4600	Much glass	" "
2	07	1010	190	Bond shrunk	
2	05	1050	192	Bond vitrified	
2	02	1110	404	Very little glass	Few sand grains fused
2	1	1150	352	Very little glass	" " " "
2	4	1210	850	Considerable glass	" " " "
2	6	1250	2107	Much glass	" " " "
2	9	1310	3100	Much glass	" " " "
2	11	1350	3200	Much glass	" " " "
2	14	1410	....	Bond fusion progressed far	" " " "
3	07	1010	35	Bond vitrified	
3	05	1050	38	Very little glass	
3	02	1110	125	Very little glass	Few sand grains fused
3	1	1150	112	Bond vitrified	" " " "
3	4	1210	224	Considerable glass	" " " "
3	6	1250	988	Much glass	" " " "
3	9	1310	1080	Much glass	" " " "
3	11	1350	1531	Much glass	" " " "
3	14	....	....	Bond fusion progressed far	" " " "
6	07	1010	106	Bond shrunk	
6	05	1050	460	Bond vitrified	
6	02	1110	1311	Very little glass	Few sand grains fused
6	1	1150	754	Bond vitrified	" " " "
6	4	1210	2000	Considerable glass	" " " "
6	6	1250	9100	Much glass	" " " "
6	9	1310	8700	Much glass	" " " "
Very hard sand to judge due to light coating of bond.					
9	07	1010	256	Little effect	
9	05	1050	101	Bond shrunk	
9	02	1110	60	Bond shrunk	
9	1	1150	60	Bond shrunk	
9	4	1210	74	Bond shrunk	
9	6	1250	16	Bond shrunk	
9	9	1310	26	Bond shrunk	
9	11	1350	Broken	Bond vitrified	
9	14	1410	128	Very little glass	
9	16	1450	191	Very little glass	
10	07	1010	118	Little effect	
10	05	1050	63	Bond shrunk	
10	02	1110	141	Bond shrunk	
10	1	1150	Broken	Bond shrunk	
10	4	1210	Broken	Bond shrunk	
10	6	1250	58	Bond vitrified	
10	9	1310	164	Very little glass	
10	11	1350	121	Very little glass	
10	14	1410	886	Much glass	Few sand grains fused
10	16	1450	986	Bond fusion progressed far	" " " "

(Continued on next page)

RESULTS OF DRAW-TRIAL TEST—Continued

Sand No.	Cone No.	Temp., Degrees Cent.	Strength, Load in Pounds	Microscopic Observation	Remarks
11	07	1010	163	Bond shrunk	
11	05	1050	Broken	Bond shrunk	
11	02	1110	43	Bond shrunk	
11	1	1150	44	Bond shrunk	
11	4	1210	16	Bond shrunk	
11	6	1250	24	Bond shrunk	
11	9	1310	41	Slight vitrification	
11	11	1350	41	Slight vitrification	
11	14	1410	42	Much glass	
11	16	1450	80	Bond fusion progressed far	
12	07	1010	136	Bond shrunk	
12	05	1050	167	Bond shrunk	
12	02	1110	194	Slight vitrification	
12	1	1150	149	Slight vitrification	
12	4	1210	270	Very little glass	
12	6	1250	1312	Very little glass	Many sand grains fused
12	9	1310	1031	Considerable glass	" " " "
12	11	1350	1640	Considerable glass	" " " "
13	07	1010	No load		
13	05	1050	58	Bond vitrified	
13	02	1110	618	Bond vitrified	
13	1	1150	95	Very little glass	
13	4	1210	1025	Bond vitrified	
13	6	1250	3300	Considerable glass	
13	9	1310	4200	Considerable glass	
13	11	1350	7900	Considerable glass	
13	14	1410	....	Fused	
13	16	1450	....	Fused	
15	07	1010	347	Bond shrunk	
15	05	1050	287	Bond shrunk	
15	02	1110	510	Bond vitrified	
15	1	1150	245	Bond vitrified	
15	4	1210	548	Bond vitrified	
15	6	1250	1772	Very little glass	
15	9	1310	1705	Very little glass	
15	11	1350	3800	Bond fusion progressed far, much glass	Few sand grains fused
16	07	1010	109	Bond shrunk	
16	05	1050	257	Bond vitrified	
16	02	1110	1130	Very little glass	Few sand grains fused
16	1	1150	199	Bond vitrified	" " " "
16	4	1210	944	Bond vitrified, very little glass	" " " "
16	6	1250	3300	Very little glass	" " " "
16	9	1310	2650	Very little glass	" " " "
16	11	1350	4300	Bond fusion progressed far	" " " "
17	07	1010	233	Little effect	
17	05	1050	254	Bond shrunk	
17	02	1110	553	Bond shrunk	
17	1	1150	230	Bond shrunk	Few sand grains fused
17	4	1210	308	Very little glass	" " " "
17	6	1250	1133	Considerable glass	" " " "
17	9	1310	877	Considerable glass	" " " "
17	11	1350	1863	Bond fusion progressed far	Many sand grains fused

sands, the initial failures of the sands are taken as shown in Table 7.

Table 7

Sand Number	Cone No.	Temperature Degrees Cent.
1	4	1210
2	4	1210
3	6	1250
4	4	1210
9	..	1470+
10	14	1410
11	..	1470+
12	6	1250
13	4	1210
15	6	1250
16	4	1210
17	6	1250

In the particular instances of sands 9 and 11, while there seems to be much glass under the microscope, there is no fusion of the sand grains (the glass formed being such that it is not a flux to the sand grains), resulting in a weak bond. Then, too, there must be taken into consideration the low percentages of clay bond in the two samples.

The above test is considered to be of value in that the operator may, with a simple furnace arrangement and a magnifying glass or microscope, determine such points at which a sand can be expected to cause trouble from failure under heat.

Local Application of Heat (Saeger's Test)

This method was originally suggested to the committee on Molding Sands of the A. F. A. by C. M. Saeger, Jr., of the U. S. Bureau of Standards, at Washington.

In this test a sample of molding sand in the shape of a bar is locally heated by an electrically heated platinum ribbon to increasingly higher temperatures. The temperature at which the sand sinters and adheres to the platinum is taken as the index of the refractoriness of the sand..

Preparation of Sample. The sand was quartered to a 1000-gram sample by the usual method and then carefully tempered with sufficient water to permit molding. The entire sample was passed through a coarse riddle and the procedure was followed of preparing the bar for cohesion test as outlined in A. F. A. Tentatively Adopted Methods of Test (June 14, 1924).

Heating Apparatus. The apparatus (Fig. 2), while the same in principle as Saeger's, was somewhat different in detail of con-

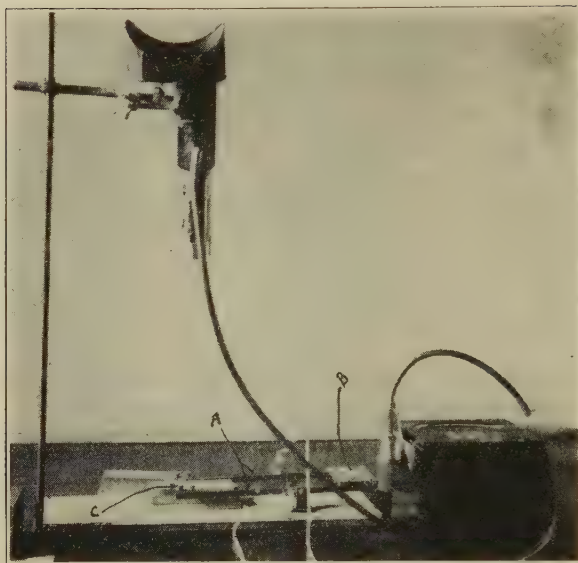


FIG. 2—SET-UP FOR PERFORMING SAEGER TEST

struction. It consists of a pair of brass bars (A), $\frac{1}{4}$ inch by $\frac{3}{8}$ inch by 12 inches, spaced $3\frac{1}{2}$ inches apart, firmly held parallel by a piece of fibreboard (B), $2\frac{1}{2}$ inches by 4 inches by $\frac{1}{4}$ inch, attached by screws near one end of the bars. At the opposite end, a platinum ribbon (C), $\frac{1}{2}$ inch wide and $\frac{3}{1000}$ inch thick, extends between the two brass bars. This framework is so mounted, on low standards to a baseboard, that the platinum ribbon may be raised or lowered at will.

The platinum ribbon may be heated to any desired temperature up to 1650 degrees Cent. by means of an electric current, supplied to it through the standards to which the brass bars are pivoted. A rheostat is provided for controlling the current and thus regulating the temperature of the platinum ribbon.

Procedure. The bar of sand is thoroughly dried and placed on the base of the heating apparatus. The current is turned on and the platinum ribbon heated to a predetermined temperature, observed by means of an optical pyrometer. The ribbon is then lowered so as to lie across the sand test bar near one end of it and allowed to remain in this position for five minutes. At the

Table 8

RESULTS OF SAEGER'S TEST					
Trial	Temperature Degrees Cent.	Remarks	Trial	Temperature Degrees Cent.	Remarks
Sand No. 1					
1	975	No glass	6	1217	No glass
2	1055	No glass	7	1242	No glass
3	1097	No glass	8	1291	No glass
4	1118	No glass	9	1365	Traces of glass
5	1187	No glass	10	1503	Stuck to strip
Sand No. 2					
1	975	No glass	6	1210	No glass
2	1035	No glass	7	1223	No glass
3	1058	No glass	8	1258	No glass
4	1118	No glass	9	1375	Traces of glass
5	1173	No glass	10	1478	Stuck
Sand No. 3					
1	975	No glass	6	1223	First sign of glass
2	1055	No glass	7	1250	Glass
3	1072	No glass	8	1288	Glass
4	1118	No glass	9	1380	Stuck
5	1167	No glass			
Sand No. 6					
1	1062	No glass	5	1288	First signs of glass
2	1097	No glass	6	1268	Glass
3	1158	No glass	7	1300	Glass
4	1158	No glass	8	1410	Stuck
Sand No. 9					
1	1035	No glass	6	1215	No glass
2	1035	No glass	7	1340	No glass
3	1104	No glass	8	1458	Traces of glass
4	1143	No glass	9	1433	Traces of glass
5	1173	No glass	10	1428	Traces of glass
					Fusion started.
Sand No. 10					
1	1035	No glass	5	1173	No glass
2	1035	No glass	6	1230	No glass
3	1118	No glass	7	1360	No glass
4	1097	No glass	8	1482	Stuck
Sand No. 11					
1	960	No glass	5	1202	No glass
2	1055	No glass	6	1198	No glass
3	1143	No glass	7	1345	No glass
4	1135	No glass	8	1474	Much glass
Sand No. 12					
1	1020	No glass	5	1210	No glass
2	1010	No glass	6	1237	No glass
3	1097	No glass	7	1261	No glass
4	1150	No glass	8	1385	Stuck
Sand No. 13					
1	1097	No glass	5	1223	Slightly stuck
2	1104	No glass	6	1275	Slightly stuck
3	1143	No glass	7	1328	Stuck badly
4	1173	No glass			
Sand No. 15					
1	983	No glass	6	1213	No glass
2	1055	No glass	7	1261	No glass
3	1104	No glass	8	1385	Traces of glass
4	1104	No glass	9	1488	Much glass
5	1173	No glass			
Sand No. 16					
1	1045	No glass	5	1190	No glass
2	1080	No glass	6	1250	Traces of glass
3	1158	No glass	7	1300	Traces of glass
4	1150	No glass	8	1410	Stuck
Sand No. 17					
1	975	No glass	5	1158	No glass
2	1045	No glass	6	1205	No glass
3	1088	No glass	7	1250	No glass
4	1135	No glass	8	1390	Slightly stuck

Table 9

SCREEN ANALYSES OF SANDS TESTED

Sand	On 6	On 10	On 20	On 35	On 65	On 100	On 150	On 200	On 270	Pan	Clay Substance	A.F.A. Fineness Factor
1	...	...	0.14	3.72	27.36	17.28	15.14	7.98	4.90	9.80	13.68	8 E
2	...	...	2.14	8.64	21.30	14.32	12.94	7.24	3.44	9.04	20.94	4 G
3	...	0.28	2.10	10.02	27.50	18.24	15.94	6.88	4.82	2.30	11.92	7 E
4	...	...	0.10	43.25	35.36	7.05	6.82	3.53	1.74	0.85	...	6 A
5	...	...	0.40	38.68	48.76	7.90	2.64	0.29	0.03	0.05	...	7 A
6	...	0.22	0.22	0.36	0.58	3.06	15.84	16.60	11.62	32.42	19.08	1 F
7	...	1.24	19.24	62.65	14.50	1.14	9.40	0.13	0.05	0.05	...	8 A
8	...	...	13.05	68.96	15.78	1.22	0.50	0.15	...	...	...	8 A
9	...	0.30	6.92	56.18	15.36	2.16	0.58	0.18	0.12	0.32	17.88	8 F
10	4.96	...	0.20	3.00	15.68	24.96	30.82	4.82	1.48	2.48	16.56	4 F
11	...	17.20	39.36	66.12	74.46	75.52	76.14	76.42	76.66	77.88	22.12	8 E
12	...	2.08	6.26	20.50	18.88	11.74	6.10	2.88	1.98	10.46	19.12	4 E
13	...	...	0.12	0.32	0.56	6.06	22.76	21.32	14.72	24.74	9.40	2 D
14	...	...	1.45	14.30	67.87	13.16	2.55	0.45	0.15	0.07	...	6 A
15	...	0.04	0.12	1.44	11.68	11.56	14.72	7.92	5.14	17.76	29.62	2 G
16	...	...	0.02	0.05	4.61	6.46	5.87	4.49	6.46	13.88	16.32	2 F
17	...	7.54	19.14	24.74	16.36	4.74	0.46	0.30	0.28	3.42	23.02	7 G

end of this time the temperature of the ribbon is read and the ribbon is raised from the test bar. That part of the sand which had been subjected to the heat is examined under the microscope for signs of sintering. These operations are repeated at increasingly higher temperatures upon fresh surfaces of the sand until marked sintering takes place as evidenced by the sand sticking to the platinum. Results of this test on the sands are given in Table 8.

Fineness Test

Screen analyses of the sands tested were made according to specifications of the A. F. A.⁹ The results obtained are given in Table 9.

The results of our tests show that there is no relation existing in the fineness test whereby we may be assisted in the determination of the refractoriness of a sand. This is easily understood when we consider the mineralogical and chemical composition of the sands in question which vary one from another to such an extent. The use of the fineness factor relative to refractoriness is limited to sands which vary one from the other only in this respect.

Table 10

SUMMARY OF TESTS

Sand No.	Begin-ning Bond Shrinkage, Deg. Cent.	Bond Vit-rified, Deg. Cent.	Tend-ency to Distort, Sag Test, Deg. Cent.	Strong Matrix, Crush-ing Test, Deg. Cent.	Softening Point of Bond, Cone Test, Deg. Cent.	Softening Point of Sand, Cone Test, Deg. Cent.	Failure, Saeger's Tests, Deg. Cent.
1	1010	1050	1167	1210	1330	1420	1503
2	1010	1050	1417	1210	1150	1450	1478
	Below						
3	1010	1010	1150	1250	1099	1480	1380
6	1010	1050	1220	1210	1330	1410	1410
9	1050	1350	1420+	1470+	1635	1600	1428
10	1050	1250	1420+	1410	1410	1600	1482
11	1010	1310	1420+	1470+	1620	1600	1474
12	1010	1110	1130	1250	1450	1430	1385
13	1010	1050	1205	1210	1290	1530	1328
15	1010	1110	1215	1250	1330	1430	1488
16	1010	1050	1220	1210	1099	1470	1410
17	1050	1150	1250	1250	1310	1420	1390

Summary of Tests

It will be noted that a general relationship exists in the figures of Table 10. To begin with, the shrinkage of the bond away from the grain occurs in all instances at temperatures below

⁹ *Standard and Tentatively Adopted Methods of Testing and Grading Foundry Sands*, A. F. A. publication, July, 1928, pp. 27-32.

1050 degrees Cent. Most of the bonds have a very short shrinkage period before becoming vitrified. In the cases of sands Nos. 9, 10 and 11, the bonding substances are of a much more refractory character and the longer shrinkage period is evidence of this fact. The temperature of sag, or tendency to distort, links, as one might expect, with the temperature at which a strong matrix is present in the cooled trial test. The differences in temperatures between the vitrification of the bond and the softening point of the bond represent the range of reaction before the bond has entered an entire liquid phase and has lost its viscosity sufficiently to cause the cone to bend over. In all but two instances (Nos. 9 and 10) the bond softens before the whole sand.

Table 11

Metal	Mixture, Per Cent	General Work, Deg. Cent.	Light Casting, Deg. Cent.	Heavy Casting, Deg. Cent.
Aluminum	Pure	760	.....	.....
"	Alloy	705	705	676
Red brass	85-5-5-5	1095	1175	1095
"	82-4-6-8	1095	1145	1065
Yellow brass	15-20 Zn	1095	1145	1065
Phosphor bronze	80-10-10	1065	1095	1040
Manganese .....	.....	980	1065	970
Acid resisting bronze.....	87 Cu, 7 Sn, 6 Zn	1175	1145	1095
Bronze	88 Cu, 4 Pb, 6 Sn, 2 Zn	1095	1145	1095
"	70 Cu, 6 Sn, 20 Pb, Others 4	1175	.....	.....
"	87 Cu, 8 Sn, 5 Zn	.....	1220-1145	1040-1065
Ni Bronze	84 Cu, 10 Sn, 2 Zn, 4 Ni	1145	1175	1145
Gun metal	88-10-2	1120	1145	1095

The figures given as results of Saeger's test have no definite relationship with the other tests. This is not surprising since the processes of heat application are so widely different. The Saeger test consists of the application of heat to the surface of the sand, while all others consist of a soaking heat throughout the specimen. It will be noted (as would be expected) that the temperatures of failure as determined by the Saeger method are for the most part higher than in other tests. The important point is that while the other tests are very interesting, it does not seem that they reproduce as nearly as does the Saeger test, the conditions met in the foundry. While the test may be improved upon in several details, it is felt that it is the best method as yet suggested for a fair test of the refractoriness of a molding sand.

Table 11 gives temperature ranges taken from a paper, presented to this association by Andrew S. Hall.¹⁰

¹⁰ Hall, A. S., *Pyrometer Control in a Brass Foundry*. Trans. American Foundrymen's Association, vol. 34, pp. 649-655 (1926).

Table 12
CLASSIFICATION OF SANDS ACCORDING TO TEST RESULTS

Sand No.	Sag Test	Softening Point of Bond Test	Draw Trial Test	Softening Point of Sand Test	Saeger's Test
1	Practically all non-ferrous	All non-ferrous and gray iron	All non-ferrous	All non-ferrous, gray and white iron	All non-ferrous, gray and white iron
2	All non-ferrous, gray iron	Practically all non-ferrous	All non-ferrous	All non-ferrous, gray and white iron	All non-ferrous, gray and white iron
3	Practically all non-ferrous	Practically all non-ferrous	All non-ferrous	All non-ferrous, gray and white iron	All non-ferrous, gray iron
4	.....	.....	.....	All types	.....
5	.....	All non-ferrous and gray iron	All non-ferrous	All types	.....
6	All non-ferrous	.....	All non-ferrous	All non-ferrous, gray and white iron	All non-ferrous, gray iron
7	.....	.....	.....	All types	.....
8	.....	All non-ferrous and gray and white iron	.....	All types	.....
9	All non-ferrous, gray and white iron	All non-ferrous and gray and white iron	All non-ferrous, gray and white iron	All types of casting	All non-ferrous, gray and white iron
10	All non-ferrous, gray and white iron	All non-ferrous, gray and white iron	All non-ferrous, gray and white iron	All types of casting	All non-ferrous, gray and white iron
11	All non-ferrous, gray and white iron	Non-ferrous gray and white iron	All non-ferrous gray and white iron	All types of casting	All non-ferrous, gray and white iron
12	Practically all non-ferrous	All non-ferrous, gray and white iron	All non-ferrous	All non-ferrous, gray and white iron	All non-ferrous, gray iron
13	All non-ferrous	All non-ferrous	All non-ferrous	All non-ferrous, gray and white iron	All non-ferrous
14	.....	.....	.....	All types	.....
15	All non-ferrous	All non-ferrous and gray iron	All non-ferrous	All non-ferrous, gray and white iron	All non-ferrous, gray and white iron
16	All non-ferrous	Practically all non-ferrous	All non-ferrous	All non-ferrous, gray and white iron	All non-ferrous, gray iron
17	All non-ferrous	All non-ferrous	All non-ferrous	All non-ferrous, gray and white iron	All non-ferrous, gray iron

Summary

Casting temperatures for ferrous work are reported as follows:

Type	Deg. Cent.
White iron.....	1410
Gray iron.....	1320
Converter steel.....	1535
Basic electric.....	1545
Acid electric.....	1535

Considering the results found in this investigation and the above tables, the following assumptions may be drawn. These sands, as far as refractoriness is concerned, are suitable for the type of work listed in Table 12. Each test is used in itself as an index for comparison.

The sands tested were as follows:

Producer's Name	Producer's Grade
1. Whitehead Bros.	2½ M
2. Paxson	Lumberton coarse strong
3. Paxson	Lumberton medium coarse strong
4. Standard Silica Co.	Ottawa sand
5. New Jersey Silica Sand Co.	No. 3 silica sand, washed
6. Albany Sand & Supply Co.	No. 1 Albany
7. Portage Silica Co.	No. 4 sand
8. Portage Silica Co.	S S sand
9. G. F. Pettinos.	Millville coarse strong
10. G. F. Pettinos.	Millville fine
11. G. F. Pettinos.	Millville gravel
12. Whitehead Bros.	Ambay sand
13. Chas. Pettinos	O stone
14. Pennsylvania Glass Sand Co.	Hatfield No. 3

Although the various tests gave different resulting temperatures of failure, Table 12 shows that the classification of the various sands according to the various tests is fairly consistent. The "Softening Points of the Sands" test gives higher refractory values than the others and is the only one which is out of line. Considering this fact and the initial cost of the Saeger equipment, it would seem that, while Saeger's test offers an ideal way for testing the refractoriness of a molding sand, the clay "Bond Softening Point," the "Draw Trial Test" and the "Sag Test" are worthy of consideration.

Before the adoption of any test as a standard, the indices of that test must necessarily show a direct relationship to the experience of commercial practice. Practically nothing is avail-

able concerning the relationship of refractoriness tests of molding sands to the experience of commercial foundry practice. Without this correlation any test is of unproved value. With this reservation in mind the sands have been classified as above. The author had no knowledge of the use to which these sands are put in commercial practice, and the classification has been made only according to the results of the various tests. This classification will undoubtedly be the cause of considerable discussion, but it is only through such discussion that a valuable test will be decided upon.

Uniformity in Core Oil—How Obtained

BY V. A. CROSBY¹ AND R. D. WYSONG,² SOUTH BEND, IND.

Interest in the quality of core oils ranks second to the age old discussion concerning quality of pig irons. The difference being that a great deal of effort has been put forth to eliminate the mysteries of various qualities in iron, while core oils until Campbell's research work presented before this Association four years ago had received very little intelligent consideration.

The old method of investigation was to eliminate oils of various trade names, by checking working conditions of the sands and rigidity of cores produced after baking. This method usually worked out admirably for some trade name oil. It must not be concluded that this is a deplorable situation because foundries have and are prospering under this plan. There are certain disadvantages which we shall enumerate for your consideration:

1. Elimination of competition by trade name buying.
2. Core oil vendors have suddenly found their contracts cancelled and goods returned because something went wrong in the core room.

The above condition may actually exist when the vendor is supplying exactly the same oil, but who knows the real reason when there are no specifications and no analyses. Of course the opposite of the above condition would be an intelligent specification which would render to all the privilege of quoting prices and at the same time protect them against sudden outbursts of the foundry management in time of trouble.

Two years ago one of the authors presented⁴ before a technical session of this association a plan by which a fair degree of accuracy could be obtained relative to the uniformity of oil re-

¹ and ² Metallurgist and Chemical Engineer, respectively, Studebaker Corp.

³ Campbell, H. L., *Qualities of Commercial Core Oils*, Trans. A. F. A., vol. 33, pp. 72 to 82 (1925).

⁴ Crosby, V. A., *Core Oil Specifications*, Trans. A. F. A., vol. 35, p. 148 (1927). Discussion of this paper appears on page 623.

ceived from time to time. The success of the plan since its inception was due to standardized chemical methods as used on pure linseed oil. This exact specification is shown in Table 1 and represents the grade of oil used at our plant during the last three years.

A number of inquiries have been received relative to the methods (in detail) for chemical analysis where a specification is being anticipated; also requests that certain oils be checked to verify analyses given. In some cases results have been gratifying while others have been very discouraging indeed.

It was recognized some time ago that if analytical methods were to become successful some recognized standard method of procedure must be followed and so stated in the specification. There are three standard methods for the determination of iodine numbers—Hanüs, Hubl and Wijs.

Table 1

CHEMICAL SPECIFICATION FOR FOUNDRY CORE OIL

Core oil must conform to the following requirements as to physical and chemical properties:

Specific Gravity @ 60° F.	.9360 Maximum
Flash Point (Cleveland Open Cup)	165-200° F.
Fire Point (Cleveland Open Cup)	190-225° F.
Iodine No. (Wijs, 15 min.)	155 Minimum
Iodine No. (Wijs, one [1] hour)	160 Minimum
Saponification No.	148 Minimum
Acid No.	30-37
Color	— Light clear amber through ½ inch section
Fish Oil	— Negative (Griffins Test)
Ash Content	.20% Maximum
Gallonage	— U. S. Liquid gallon @ 60° F.

The purchaser reserves the right to subject each shipment, when received, to the above inspection and tests. Failure to pass any of them may be cause for the return of the shipment for full credit plus carrying charges both ways.

The Wijs method seems to be in best repute and is used by the authors for all iodine determinations. However, there are certain oil companies—both core oil and linseed who still use the Hanüs method. It is a recognized fact that these two methods do not give like results on the same oil, however, there is a correction that can be applied when the particular method used is specified. The other chemical determinations in a satisfactory core oil specification are standard and do not lend themselves to much variation in the hands of competent chemists.

Iodine numbers, as effected by absorption time of solution and obtained by the Wijs method, are shown in Tables 2, 3, 4 and

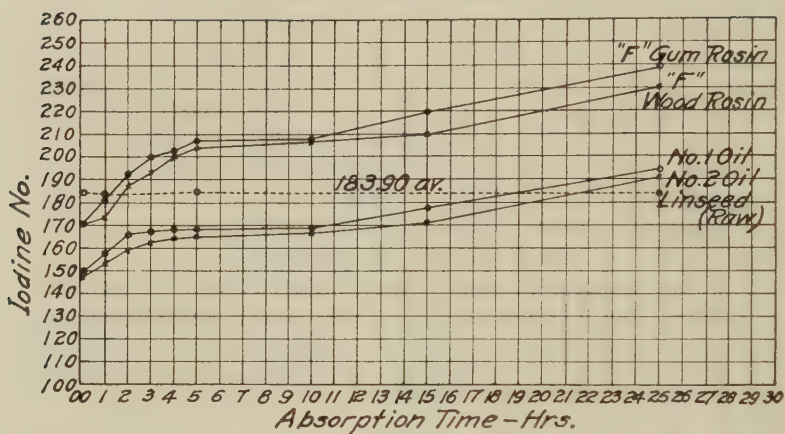


FIG. 1—INCREASE OF IODINE NUMBER CAUSED BY LONGER ABSORPTION TIME WITH WIJS SOLUTION. COMPARISON OF OILS AND THEIR ROSINS. DATA TABULATED IN TABLE 2.

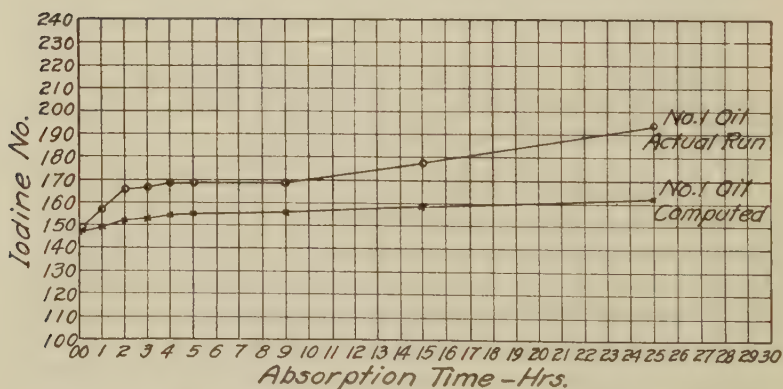


FIG. 2—INCREASE OF IODINE NUMBER CAUSED BY LONGER ABSORPTION TIME WITH WIJS SOLUTION. COMPARISON OF ACTUAL AND COMPUTED IODINE NUMBERS. DATA TABULATED IN TABLE 3.

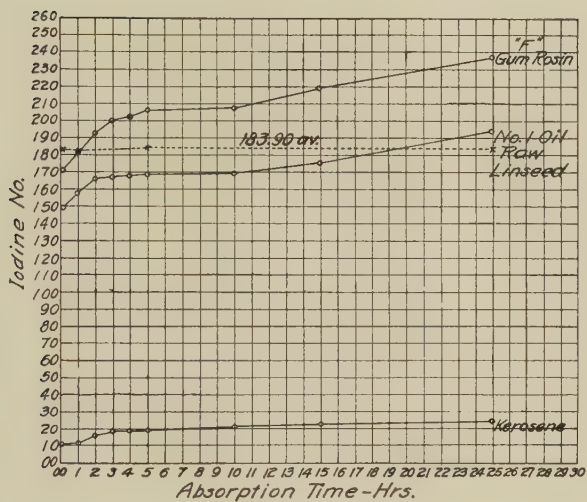


FIG. 3—INCREASE OF IODINE NUMBER CAUSED BY LONGER ABSORPTION TIME WITH W₁S SOLUTION. COMPARISON OF NUMBER 1 OIL WITH ITS CONSTITUENTS. DATA GIVEN IN TABLE 4.

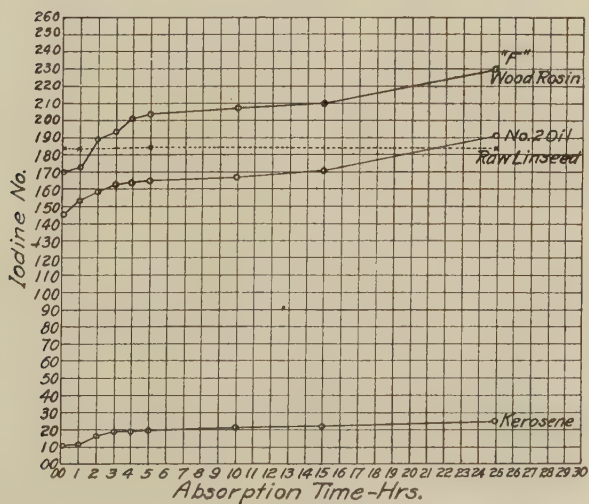


FIG. 4—INCREASE OF IODINE NUMBER CAUSED BY LONGER ABSORPTION TIME WITH W₁S SOLUTION. COMPARISON OF NUMBER 2 OIL WITH ITS CONSTITUENTS.

Table 2

DATA FOR FIG. 1

Time	"F" Gum Rosin	"F" Wood Rosin	No. 1* Oil	No. 2* Oil	Raw Linseed
15 min.	170.20	170.00	149.24	146.60	183.96
1 hr.	180.26	173.26	157.38	153.34	183.00
2 hrs.	192.43	182.36	166.09	158.63	.....
3 hrs.	200.10	193.20	166.83	162.40	.....
4 hrs.	202.40	200.86	168.10	163.96	.....
5 hrs.	206.26	203.93	168.40	164.59	184.21
10 hrs.	207.76	207.00	168.88	167.65	.....
15 hrs.	219.76	210.76	178.16	170.94	.....
25 hrs.	237.88	230.28	194.30	191.27	184.43
50 hrs.	254.60	246.24	211.93	206.13	.....
100 hrs.	256.30	247.00	220.59	216.91	.....

*No. 1 Oil=60% (in weight) Raw Linseed; 20% (in weight) "F" Gum Rosin; 20% (in weight) Kerosene. No. 2 Oil=60% (in weight) Raw Linseed; 20% (in weight) "F" Wood Rosin; 20% (in weight) Kerosene.

Table 3

DATA OF FIG. 2

Time	No. 1* Oil, Act.	No. 1 Oil, Comp.	Diff.	"F" Gum Rosin	Raw Linseed	Kerosene
15 min.	149.24	146.51	2.73	170.20	183.96	10.65
1 hr.	157.38	148.74	8.64	180.26	183.00	11.75
2 hrs.	166.09	152.04	14.05	192.43	.....	16.06
3 hrs.	166.83	153.08	13.75	200.10	.....	18.59
4 hrs.	168.10	154.58	13.52	202.40	.....	18.80
5 hrs.	168.40	155.41	12.99	206.26	184.21	19.11
10 hrs.	168.88	156.16	12.72	207.76	.....	21.38
15 hrs.	178.16	158.67	19.49	219.76	.....	21.90
25 hrs.	194.30	162.84	31.46	237.88	184.43	24.64
50 hrs.	211.93	.....	.....	254.60	.....	.....
100 hrs.	220.59	.....	.....	256.30	.....	.....

*No. 1 Oil=60% (in weight) Raw Linseed; 20% (in weight) "F" Gum Rosin; 20% (in weight) Kerosene.

Table 4

DATA OF FIG. 3

Time	No. 1* Oil	"F" Gum Rosin	Raw Linseed	Kerosene
15 min.	149.24	170.20	183.96	10.65
1 hr.	157.38	180.26	183.00	11.75
2 hrs.	166.09	192.43	.....	16.06
3 hrs.	166.83	200.10	.....	18.59
4 hrs.	168.10	202.40	.....	18.80
5 hrs.	168.40	206.26	184.21	19.11
10 hrs.	168.88	207.76	.....	21.38
15 hrs.	176.16	219.76	.....	21.90
25 hrs.	194.30	237.88	184.43	24.64
50 hrs.	211.93	254.60	.....	.....
100 hrs.	220.59	256.30	.....	.....

*No. 1 Oil=60% (in weight) Raw Linseed; 20% (in weight) "F" Gum Rosin; 20% (in weight) Kerosene.

5 and the data plotted in Figures 1, 2, 3 and 4. It is evident that iodine numbers mean practically nothing unless the time of absorption of the oil in the iodine solution is specifically stated. This refers to oils carrying a percentage of rosin. Linseed is not affected by time as shown in the charts of Figs. 1 to 4.

The progressive absorption of rosin from Wijs solution is mentioned on page 496, Vol. I of Lewkowitsch on Chemical technology. It was expected that with the complete solution of rosin in mineral oil and linseed that this progressive increase would be eliminated due to the more perfect dispersion of the rosin in solution.

The specifications of Table 1 represent one of a possible one hundred kinds of core oils possible to make. The idea is to specify something and stick to it until additional research indicates something better than rewrite your specification.

Table 5

DATA OF FIG. 4

Time	No. 2* Oil	"F" Wood Rosin	Raw Linseed	Kerosene
15 min.	146.60	170.00	183.96	10.65
1 hr.	153.34	173.26	183.00	11.75
2 hrs.	158.63	189.36	.....	16.06
3 hrs.	162.40	193.20	.....	18.59
4 hrs.	163.96	200.86	.....	18.80
5 hrs.	164.59	203.93	184.21	19.11
10 hrs.	167.65	207.00	.....	21.38
15 hrs.	170.94	210.76	.....	21.90
25 hrs.	191.27	230.28	184.43	24.64
50 hrs.	206.13	246.24	.....	28.00
100 hrs.	216.91	247.00	.....	....

*No. 2 Oil=60% (in weight) Raw Linseed; 20% (in weight) "F" Wood Rosin; 20% (in weight) Kerosene.

There exists an abnormal increase in iodine number with increased time absorption on core oil Nos. 1 and 2 (Table 2 and Fig. 1) which contain 20 per cent by weight of rosin in comparison with pure rosin for the same length of time. We are not able to account for this condition or phenomenon.

Conclusions: Although the major portion of this paper has been devoted to the iodine numbers of oils, I would not have you lose sight of the importance of saponification number, specific gravity, color, acid number, etc. In fact every item must be carefully checked.

Much of the data presented in the charts the authors offer no explanation for. It is a matter of cold facts from which we

are able to understand the characteristics of certain of the raw materials used in producing core oils and most assuredly accounts for the discrepancies encountered in results from different laboratories on same samples.

It is hoped that some interest may be created whereby additional information can be utilized for the mutual benefit of the core oil manufacturers and the foundrymen.

Exact uniformity of analytical methods covering the chemical constituent to be determined in the hands of a competent analyst will most assuredly produce excellent results.

Foremen's Conferences at The River Works, General Electric Company, Lynn, Mass.

BY M. H. MELLEN,* LYNN, MASS.

In modern industry the foreman is preeminently the man who is responsible for getting out economical production and maintaining harmony among the working force. He has well been called the key man in industry. On one hand, he receives instructions from the management and, on the other, he must instruct the working force. In addition, he must answer the questions of his men and try to settle their difficulties satisfactorily.

To the men, the foreman is the expression of company policies. To the management, he conveys the attitude of his men toward the company. Because of this, many believe he can exert a greater influence for good or evil than others in industry.

Of course to a very large extent the value of the foreman depends upon his knowledge of production methods. But to be successful the modern foreman must do more than just get out the production. He must cooperate with other departments; he must maintain the right relations with his men; he should have a knowledge of company policies as well as some knowledge of the methods of financing.

To bring information on these subjects to the foreman, courses have been introduced into industry called foreman training.

The term foreman training as commonly used is very broad and may mean anything from a discussion of simple production methods to a discussion of problems confronting the management; in fact, there seems to be no limit to which this training may not reach.

But, if the aim is only to make the foreman a better leader and producer in his particular industry, much of this material dealing with managerial problems may be omitted.

*Supervisor of Education, The River Works, General Electric Co.
Discussion of this paper appears on page 610.

Methods of Training

Foreman training courses have been developed along several quite different lines and it appears that each course has some excellent content to recommend it. Perhaps what would succeed in one plant might not be so successful in another. However, there are certain principles which must be included in any course if results are to be obtained.

The lines upon which courses have been developed are as follows:

The Lecture Method.

The Lecture Discussion Method.

The Conference Method.

The Correspondence Method.

The lecture method may be followed by arranging for speakers who may come either from within the plant or from the outside to address the foremen on disconnected subjects or to present a program of related topics.

The lecture discussion method usually calls for a twenty or thirty minute talk on the topic by an instructor, after which he endeavors to draw out questions on the subject from the foreman and use the remaining time for discussion. In this, much depends upon the ability of the instructor to get the foremen talking.

The conference method is conspicuous by the entire absence of lectures. The success of this plan depends upon the ability of the leader to draw the foreman out sufficiently to think, talk, and discuss the problems presented by the group.

The correspondence method offers an opportunity to study the subject matter at home.

The fact that foreman training is at present given such widespread attention is an indication of the necessity for good foremanship in our industrial system. It seems that to assure good foremanship some method of training should be undertaken, but, before launching any foreman training course, it is important that the matter be carefully studied and the method selected which seems best adapted for the plant.

Foreman training was first introduced at the Lynn Works of the General Electric Company in 1919. The plan adopted at

that time was to invite the foremen to join a group which met during working hours. The discussions were developed around hypothetical questions involving shop problems. At the close of these conferences, criticisms made by some of the foremen were, that no conclusions were reached in the conferences and little of value was derived from them, but, others believed that regardless of these criticisms, at least the foremen became acquainted and for that reason alone, if for no other, the conferences were worth while.

As a result of these criticisms a quite thorough check-up was undertaken. This check-up showed that many of the foremen had profited by their attendance and likewise, it was thought the company benefited. But the management did not believe that the work had produced the results expected. Consequently, it was stopped in 1922.

After the lapse of two years, the management decided to again inaugurate foreman training but on a new plan.

This time before undertaking the work, division superintendents were called into conference with the management and the following was agreed upon in principle.

1st. To be successful the training plan arranged must have the active interest and full cooperation of all division superintendents and foremen.

2nd. Only topics of every day importance to the foreman should be discussed at the conferences.

3rd. Papers on the topics should be prepared by and discussed with an instructor selected because of his active contact with the subject.

The conference groups should include foremen, assistant foremen, leading hands (the production, cost, stock, and time study clerks and inspectors), and perhaps others not on the supervisory list but considered to possess qualities of leadership. The groups not to be larger than fifteen, as it is believed better results are obtained with small groups.

The chairman of a conference group should be a man who is acquainted with the members and one in whom they have confidence. Keeping the same chairman for all meetings assures

better results. He should be fair, tactful, have good judgment and possess a sense of humor. It will also contribute to the success of the conferences if he has a knowledge of the subjects discussed. He should strive to draw out discussion, giving the others an opportunity to express their opinion.

A record of all meetings should be kept in the form of minutes, wherein all conclusions are recorded. One member of the group may act as secretary. These minutes should be a briefly summarized statement of the opinions and conclusions reached. The names of conference members should not be used in connection with any discussion. Anything recorded pertaining to the discussion should appear as the opinion of the group and not the statement of some individual.

When this plan was first put in operation, twenty minutes were allowed for reading the paper and forty minutes for discussion. It was soon found advisable to extend the time to one and one-half hours or even to two hours when necessary to finish the discussion; also reading the paper at the conference was discontinued, mimeographed copies being distributed to the members one week in advance for study. This change permitted the entire time to be devoted to discussion and worked out much better.

Everything possible should be done to guard against impressing the foreman that it is a school or class he is attending. For that reason the matter of outside preparation should be dealt with carefully. But, if a foreman is ambitious and interested in improving himself, he will be willing to make an effort to learn about the subjects discussed. He will read the papers and bring in questions on the subject that arise in his mind. The foremen are not checked to see if the papers are read, neither are they given any quiz at the close of the conferences.

It will be noted that the plan finally adopted followed the conference method.

The topics discussed at the conferences are:

1. The Foreman and His Responsibilities.
2. Industrial Relations.
3. Production Control.
4. Planning of Methods.
5. Inspection for Control of Quality.
6. Stores and Stocks.
7. Cost Finding.
8. Wage Systems.
9. General Accounts.
10. Engineering and Drafting.
11. Salvage of Waste.
12. Safety and Health.
13. The Suggestion Plan.
14. Plans of Representation.
15. Leadership.
16. The History of Industry.

Foreman Training for Apprentices

An extensive apprenticeship system is maintained at the Lynn Works and many promising young men are selected from the graduates to fill executive positions in the plant. The benefits from the foreman conferences with the foremen were so manifest it was a perfectly natural step to extend this training to the apprentices.

Foremanship training was first included in the curriculum of the apprentice school about one year ago. The apprentices take this training during the last three months of their apprenticeship.

It is too early to look for any benefits from this training with the apprentices, but, it is believed these young men are potentially better material for foremen as a result of the training.

Testimonials

As an evidence of what some of the foremen of the plant

think of foremen's conferences, I quote one of several letters that have come to my hands.

"Mr. N. J. Darling, Mgr.

"The members of Group 1, Section 6, of the Foremen's Conferences desire to express to you their thanks and appreciation for granting them the privilege of participating in these conferences.

"Each and every one agreed that all departments in the Turbine Building have been brought into closer relations with each other and have derived more benefit than can be expressed in words.

"Permit them, through me, to thank you, the management, and each of the leaders for the time and effort put into these meetings to make them a success and it is our hope that the management has gained as much from them as we have.

"Signed—A. V. Felton, Secretary."

Results from Foreman Training

The question naturally asked is, What will be gained from foremen's conferences? Or in other words, Do they pay dividends? The dividends from foremen's conferences are to a certain extent intangible. Unfortunately, this is a problem that cannot be reduced to an accurate accounting basis. From the standpoint of direct expenditures, it is only a matter of the time of the foreman while away from his job and in attendance at the conference. But, if the actual benefits derived from foremen's conferences are to be measured they may be summed up as showing in: Increased production, reduced costs, reduced labor turnover, fewer accidents, a clearer understanding of company policies, and a greater degree of interdepartmental team work, and perhaps, the conferences may help the foreman to see his job in a new light and realize how his personal characteristics affect the morale of the organization.

Some Notes on Foreman Training

BY W. F. COLEMAN,* CHICAGO, ILL.

As we study or associate ourselves with a particular problem we develop certain facts or principles which when listed and defined act as a guide for further development.

In these remarks I will try to list such facts and tendencies in foreman training as have been revealed to me through literature, conference leadership and contact with many foremen in many lines of industry.

To begin I do not find as much training of foremen as the literature and prominence given the subject would lead us to believe. It seems training is almost always sold to the management rather than bought by the management. I find much so-called foreman training is merely get togethers of foremen, either for social benefit or to discuss routine problems.

When asked as to the success of a course the answer is always in terms of attendance and enthusiasm and not in gain to management. It will always be a very difficult matter to measure the results of foreman training in dollars and cents.

Management, as a rule, does not want to teach and is not capable of teaching. Men do not want to study except as they see a gain as a result of study.

Supervisory incentives afford the desire for study and provide the reward for doing so.

The smaller the plant the fewer conferences can be held during business hours.

The nearer the plant approaches the jobbing shop the less chance there is for conferences during business hours.

The conference type of instruction seems best fitted for foreman training.

Practically all text material covers the human side.

*General Superintendent, W. A. Jones Foundry and Machine Co.
Discussion of this paper appears on page 610.

Foreman training of the right nature should help because concentrated study on any problem always means progress.

An idea of real training would be as follows:

First, have a definite industrial relations program outlined by management.

Second, to have that program properly interpreted and taught to the supervisory force by competent teachers so that it is properly administered and upheld.

Report of Apprenticeship Committee

To Members of the American Foundrymen's Association:

In planning the work for the past year, the apprenticeship committee has acted on the principle that the greatest need of foundry apprenticeship is a stimulation of greater interest in this important activity.

Foundrymen have a tendency to neglect the human side of their enterprises. They do not exert the same effort to build up trained organizations as they do to build efficient and well equipped foundries.

Accordingly, the committee has devoted its best efforts to keeping the subject of apprentice training constantly before the eyes of the members.

Circular Letters

In order to carry out this plan, a series of circular letters was planned by the members of the committee and issued from the executive office of the association. Six letters were written covering the following points:

- The need of foundry apprenticeship;
- Several advantages of apprentice training in the industry;
- Apprenticeship the only means of attracting the best young men to the foundry industry;
- Foundry apprenticeship pays;
- Success in foundry apprenticeship depends upon thorough understanding of the work.
- Announcement of the Apprenticeship Session for the present convention.

Apprentice Contests

Contests for apprentices in pattern making and iron and steel molding have again been held in connection with the present convention.

These contests develop interest in apprenticeship on the part of the apprentices and on the part of foundry operators. Particularly, they point out to the apprentices that the greatest association of foundrymen in the country is sufficiently interested in their progress to stage contests of this kind.

Apprenticeship Session

The Apprenticeship Session of the present convention has been based upon suggestions made by those who attended last year's session. Those who attended the session were requested to register and a letter was afterwards sent to them asking for ideas whereby the sessions might be improved.

The reasons for training apprentices and methods of training will both be covered by qualified speakers. Thereafter time will remain for thorough discussion.

Contact with Schools

In addition to carrying on activities already instituted, the committee will attempt in the coming years to interest schools and students in the foundry industry and in foundry training. How this will be accomplished is to be determined at the present convention.

Appreciation

The apprenticeship committee wishes to thank the officers and directors of the Association for their continued support and encouragement of the work of the Committee.

Respectfully submitted,

C. J. FREUND, *Chairman,*
Apprenticeship Committee.

Foundry Sand Research Report of the Technical Director—1929

To the Members of the American Foundrymen's Association:

It is now some 7 years since the Joint Committee on Molding Sand Research was organized under the auspices of the A. F. A. and the Engineering Division of the National Research Council, although later the committee became a strictly A. F. A. body.

This may, therefore, be a fitting time to consider briefly what has been accomplished since the initiation of sand research work.

At the time of the organization of this work, it seemed desirable to place each of the several lines of investigation in charge of sub-committees in order, no doubt, to develop greater efficiency and expedite matters. This was a wise step, partly because the several lines of investigation and experimentation to be followed have proved to be important and time requiring.

The sub-committees organized at the start, therefore, were those on standard tests, conservation and reclamation, and geological surveys. Later, one on grading was also established. Brief reference may be made to the work thus far accomplished by these committees.

Committee on Geological Surveys

The committee on geological surveys has practically completed its work, after having induced some 20 states to undertake a survey of their sand resources, the tests on the samples collected by them being carried out under the auspices of the A. F. A. either at Cornell University or at the Bureau of Standards.

The results of these tests have been for the most part published in the A. F. A. Transactions, as well as in special reports issued by some of the State Surveys.

While some have questioned the practical value of this work, we have the assurance of several state geologists that it has

served to call the attention, in more than one case, of local foundrymen to nearby deposits of sand which they could use but had not done so.

The Committee on Tests

The committee on tests, which has functioned continuously since 1921 with comparatively little change of personnel until recently, has perhaps had the hardest job of any of the committees, and too much cannot be said of the enthusiastic and tireless efforts of individual members to make the work of the committee a success. In order to expedite the work, special problems have from time to time been assigned to sub-committees.

The most important results of this committee's efforts thus far are the development of several standard methods for testing the properties of molding sands, including tests for permeability, strength, and fineness, dye absorption, and moisture.

It is a source of gratification to find how widely at least the first two of these tests are used for sand control work in different foundries.

Some concern has been caused by the development of several different strength tests, viz., the bar test, tensile test, compression test, and shear test, all for the purpose of measuring the strength of sands.

This naturally led to some confusion in view of the fact that many foundrymen, who were about to adopt the standard tests for control work, did not know what strength test to select.

I think it should be said in defense of the committee on tests, that the use of all these different kinds of strength tests was not initiated or recommended by it, but it did feel it incumbent upon itself to make an effort to recommend a standard of procedure for making each one of these four strength tests, so that different individuals or foundries using the same test could check each other intelligently.

Having done this the committee then proceeded to recommend that the compressive test should be designated as the standard one.

This, of course, did not rule out the use of the others if any foundryman chose to use one of them. Indeed, some may get

better results with one than another, and the reason for this presents an interesting problem to be worked out.

This incidentally leads to another matter. None of the machines which are now being sold for testing sand are to be designated as A. F. A. standard machines except the permeability apparatus, which, in its original form as illustrated in the pamphlet on tests, was designed by the committee on tests.

It is true, of course, that several different types of apparatus have appeared on the market for making some one test, as in the case of the compression test, but this is a matter over which neither the committee nor the A. F. A. has any control. Anyone purchasing any of these machines, however, should satisfy himself that it performs the test according to A. F. A. standards.

It is probably true that at the majority of foundries where sand testing is followed, the A. F. A. methods are used, but in a few there has been some intelligent modification of them to meet special conditions.

It became evident to the committee on tests that the testing of cores represented such a large problem in itself that it was desirable to place it in the hands of a sub-committee with Mr. E. R. Young as chairman.

The sub-committee has already presented two reports, the first outlining a method for testing the tensile strength of baked cores, and a later one recommending that the strength might also be determined by the transverse test, these two tests being recommended as tentative standard tests.

Since then, however, the sub-committee on core testing has done considerable work formulating and outlining plans for future work, each problem to be investigated by several members of the sub-committee selected by Chairman Young. The details of their plans and the progress which they are making will be given in Mr. Young's report (Page 558), so that they need not be repeated here. It may be remarked, however, that the energy with which they are attacking their tasks speaks well for results to be obtained in the future.

Speaking in broad terms of the future work of the committee on tests, it seems to me that this, in general, may follow two lines, viz.: 1, Improvement in accuracy or ease of manipulation

of tests already recommended; 2, recommendation of new tests for the determination of properties not covered by those already suggested.

Committee on Reclamation and Conservation

The work of this committee has been of importance in calling to the attention of the foundry industry the extent to which conservation and reclamation work has been developed, and the saving which it has effected for the foundries.

As Mr. Harrington, chairman of the committee states, there is little doubt as to the magnitude of the conservation movement through the intelligent use of clay bonds and highly bonded sands.

The committee is cooperating with the Committee on Tests in developing methods for the evaluation of bonding clays and high bonded sands.

Committee on Grading

It has become evident, in view of the wide variety of sands being used, which varied not only as to texture, clay content, etc., that it would be highly desirable if some grading of each of these properties could be made.

One object of such a grading would be to develop the use of one uniform system of grading for all sands, instead of having a number of separate and widely different systems, which have led to endless confusion.

A committee on grading, with A. A. Grubb as its active chairman, was appointed, and after two years of strenuous work and the study of a great mass of data, the committee was able to recommend practical methods for grading or classifying foundry sands as regards their fineness and clay contents.

Mr. Grubb points out in his last report that while the classifications adopted by the committee have not been used as widely as had been hoped, there is no doubt but that they have been of considerable value to the foundry industry. Possibly their greatest value, he suggests, has come from the efforts of sand producers to produce uniform sands, and it is now quite possible to buy sands of certain grain size and clay content specifications.

As pointed out further, there is a definite need for classification based on quality of clay, but more information is needed before this can be intelligently handled.

Other possible bases for classification are permeability, bond and chemical composition.

Conclusions

Permit me to say in conclusion that the interest which members of the several committees have shown in their work, even though it has involved the sacrifice of much time on their part, has been a guarantee that their labors would be crowned with success, while on the other hand the encouraging reception which their recommendations have been given by the members of the A. F. A. has been a source of great inspiration.

Perhaps no one thing is better evidence of the interest taken by the A. F. A. in the sand research work than the fact that when the new edition of the sand test pamphlet recently appeared, there were over 1,700 requests for it.

Respectfully submitted,

H. RIES, *Technical Director,*
Committee on Molding Sand Research.

Report of the Committee on Conservation and Reclamation

To the members of the American Foundrymen's Association:

The sub-committee on conservation and reclamation has held no meeting since the convention in Philadelphia and has not been active in any way except to again canvass the various foundries, suppliers of clay bond and molding sand, in order to determine the extent to which the program of conservation reported at the 1928 convention has continued in the various foundries throughout the country.

The reports from the producers of clay bond show a very appreciable increase in production and sales, over 250 per cent for 1928 as compared to 1927.

To date, replies have been received from four molding sand producers. One producer who supplies both molding sand and clay bond states that there has been an increased tonnage of clay bond used during the last two or three years. The other molding sand producers state that they are in no position to advise as to the use of an extended amount of clay bond.

The various foundries who have answered the inquiries of the Committee have merely reconfirmed the reports of previous years to the effect that conservation through highly bonded sands or clay has proved economical both from the standpoint of conservation of material employed and through a reduced amount of defective.

There is noted below typical replies from various foundries. There is included in the first group, the replies from five of the countries largest automotive foundries. In the second group there is included the replies from five large representative foundries manufacturing miscellaneous castings other than automotive parts.

Discussion of this report on page 562.

Replies from Foundries Producing Automotive Castings

"Would say that we are still using clay bond in our foundry operation and are apparently very successful in the application for casting motor blocks and sundry castings which go into automobiles.

"We figure that this is saving us an average of \$1.50 per ton on sand used, as we are using 60 cents lake sand against \$3.50 molding sand.

"I cannot say that it gives us any better castings, but will not say that it has increased our scrap in any way at all. We are able to control permeability and bond strength very easily."

"We have been using . . . for about two years as a rebonding agent in our molding and facing sands. At present, the volume of our heap sand is kept up mainly through the use of refuse sand from the cleaning room.

"We find its application to be economical both from the standpoint of the conservation of new sand and that of cleaning room costs. Its use also enables us to maintain better control over our molding and facing sands."

"I have your letter of February 8 and am glad to report that we still find the use of . . . and . . . profitable, and that we have bought no molding sand since our last report."

"As we have used clay bond for years for the purpose of saving new sand and reclaiming old sand and are still doing so, it is almost needless for me to say that we do think that it is proving very successful for such purposes and that, in our opinion, it is a direct help in the reduction of defective castings."

"We consider clay bond successful and economical on certain classes of work and would not revert to new sand on this type of work. On other classes, we have not been as successful; this applies to cylinder block facing.

"In general, we consider the addition of about 15 per cent of new molding sand to the synthetic mixture beneficial."

Replies from Miscellaneous Foundries

"This company is still, to some extent, using clay bond. I think, however, it is fair to say, as a generalization, that we are less favorably impressed with that practice than we were a year ago. Certain difficulties which we encountered and which some of our people think were due to clay bond did actually disappear to a considerable extent when we went back to the use of natural molding sands, which may or may not have been a coincidence. All this, of course, does not apply to our steel casting practice."

The above foundry is the only foundry to report the somewhat unfavorable experience.

"We are still using clay for bonding molding sand, but in slightly greater amounts than we were a year ago.

"The results are as reported at that time, that is, we are able to produce a better quality of casting with less scrap and at a lower expense for molding sand."

"Answering your letter of the 18th, we have been using clay bond for the past four years, and find it very economical, as we use about one-third of the new molding sand that we formerly used."

"Replying to your inquiry of February 18th, beg to advise that we have made no change in our method of reclaiming and preparing molding sand with clay bond as reported to you last year.

"We still feel that we are getting cleaner and better castings at a considerable saving in raw material."

"Replying to your committee letter on clay bond. We are completely wedded to the use of synthetic sand by application of clay bond to our heap sand. We feel it is not only more economical but produces more uniformly good castings.

"We use what you term technical control over our sand but do not let this completely dominate our molding foremen."

In conclusion, the committee can only reiterate the position it took in its report of 1928 in which it pointed out:

(1) The importance of sand testing and control as an adjunct to a successful conservation program.

(2) The definite possibilities in the field of sand conservation through the application of intelligent methods and proper materials which are worthy of consideration of all foundries endeavoring to produce quality castings economically.

Respectfully submitted,

R. F. HARRINGTON, *Chairman,*
Committee on Conservation and Reclamation.

Report of Committee on Standard Tests

To the Members of The American Foundrymen's Association:

In making the annual report for the Committee on Tests we desire to point out that while several important pieces of work have been undertaken by the committee during the past year, the time has been too short to complete any one of them, and give them the attention which their importance merits. It is possible, however, to report marked progress.

Most of the problems now under investigation have been referred to sub-committees of the main committee for investigation and to report back to the latter. The sub-committees are as follows:

Sub-Committee on Mold Permeability and Hardness: The task of this sub-committee has been to devise a nozzle or tip which could be connected with the regular permeability apparatus by means of a tube, and used to determine the permeability of both the surface and interior of the mold. It was recognized that the same type of tip would not be suitable for both points of determination. The sub-committee has, therefore, devised one tip for the surface permeability determinations which was described in last year's report, and it is now experimenting with a second one for interior permeability.

The other problem which was assigned to this same sub-committee was that of developing a method, or selecting a piece of apparatus for determining the hardness of the mold.

The sub-committee has been considering and experimenting with several types of hardness testers, but is not yet ready to recommend any particular type. Whichever one is employed it is recognized that it should be light, easily operated, and usable for either a vertical or horizontal surface, dry or green sand, coarse or fine material.

Sub-Committee on Core Testing: At the Philadelphia convention it was recommended that both the tensile strength test and the transverse strength test be given the status of tentative standard methods for testing baked cores. Certain modifications were also recommended in the method of making the briquettes for the tensile strength test.

Since then the sub-committee with E. R. Young as chairman has been enlarged, and a somewhat detailed and thorough program of work has been initiated, which is outlined in his report, attached herewith. See page 558.

It is hoped that when this sub-committee completes its investigations, many puzzling problems dealing with the testing and behavior of core mixtures will be cleared up.

Sub-Committee on Bonding Clays: This sub-committee, as announced last year, was organized for the purpose of developing methods for testing and evaluating clays.

For this work some 20 different types of clays sold for bonding sands have been selected, these representing as wide a range of materials as possible.

The tests being carried out up to the present include: 1. Dye adsorption and suspension tests (by A. A. Grubb); 2. Refractoriness tests (by C. M. Saeger, Jr.); 3. Permeability, compression and tensile strength tests on green and baked clay-sand mixtures. These mixtures consist of No. 20 Ottawa sand, with 3 and 6 per cent of clay, and in the case of bentonites, with 1 and 2 per cent of clay in addition. Each of the mixtures is being made up with 4, 6 and 8 per cent moisture. Other amounts may be tried later.

The work is well under way, but the sub-committee has no definite report to make as yet.

It is also expected to check the results obtained in the laboratory with those obtained in the foundry.

Durability of Sand: This is an important problem which the committee because of press of other work has been unable to take up. During the past winter it has, however, been referred to a special sub-committee from whom it is hoped results will be obtained in the near future. It is recognized of course that several methods for determining this property have already been described, and while one of these may prove satisfactory, still it

is a fixed principle of the committee not to recommend any method of test without giving it a **thorough trial**.

Future Work: Having outlined the work under way at present it may be well to note work to be carried out in the future, for although the committee on tests has been functioning for seven years, its labors do not seem to be terminated.

The future work of the Committee on Tests will, in general, follow two lines, viz.:

1. Development and recommendation of new tests.
2. Improvement of those already recommended.

Among the problems still to be taken up by the Committee on Tests are:

1. Rapid and accurate methods for determining moisture, colloids, and clay.
2. Physical properties of sand as affected by the degree of ramming.
3. Effect of grain shape and size on physical properties.
4. A test for measuring the flow of sand in molds.
5. A test for sea coal in molding sands.

As illustrative of the possible improvement of tests, reference may be made to the fineness test, which was supposed to have been developed to a state of efficiency, such that fairly uniform results could be obtained by different observers.

It has recently been found, however, that while any one operator can check himself very closely, the same is not always true of two persons, working on the same sand.

In other words, the conditions for making the fineness test, while insuring fairly accurate results, do not appear to guarantee absolute accuracy.

We have found for example that such factors as the minimum diameter of the siphoning tube, rate of siphoning off the clay, manner of siphoning, and cleanliness of sieves all seem to exert an influence.

As a result of our experience with the test, the committee recommends the following modifications of it: The minimum internal diameter of siphoning tube shall be 6 mm.; the bottom of the tube shall be placed one inch from bottom of jar, and the lower end of tube shall be curved upward being bent with a

Table 1

TESTS OF BAKED SAND CORES			
Sand No.	Dense End Up	Dense End Down	Difference in Lbs. Per Sq. In.
1	72	57	15
2	82	44	38
3	64	49	15
4	80	44	36
5	72	41	31
6	62	49	13
7	64	52	12
8	97	51	46
9	52	24	28
10	60	21	39
11	54	39	15
12	61	28	33
13	42	23	19
14	47	21	26
15	116	104	12
16	131	78	53
17	76	59	17
18	82	51	31
19	81	61	20
20	92	67	25
21	63	44	19
22	67	55	12
23	68	51	17
24	81	78	3
25	44	33	11
26	55	29	26
27	52	35	17
			629
			27 = 23.3

Table 2

TESTS OF GREEN SAND CORES			Lbs. Per Sq. In.
Sand No.	Dense Side Up	Dense Side Down	Algebraic Difference
1	10.1	10.2	-0.10
2	9.0	9.2	-0.20
3	9.9	8.9	+1.00
4	11.55	11.6	-0.08
5	11.70	11.0	+0.70
6	10.25	10.9	-0.65
7	7.25	7.6	-0.35
8	6.1	5.7	+0.40
9	11.45	11.0	+0.45
10	12.4	12.4	....
11	10.9	10.8	+0.10
12	9.65	9.9	-0.25
13	9.2	9.8	-0.60
			-0.50
			13 = 0.038

half-inch radius. The object of the upward curvature is to prevent suction of settled grains from bottom of jar. The tube is put in place just prior to siphoning. The outer leg of the siphoning tube is to be 2 inches longer than the inner one.

The committee is also experimenting with a new type of settling jar which eliminates the need of a filter after the clay substance has been removed.

Some question has also been raised as to whether the clay content as now determined in the A. F. A. fineness test, represents true bond, and the Committee on Tests proposes to give further attention to methods for determining more accurately true clay bond.

A somewhat interesting problem has also come up in connection with the compression test.

It has been found, for example, that if naturally bonded baked sands are tested in compression, a greater strength is almost invariably obtained if the cores are tested with the top end up as rammed, than if they are tested bottom end up as rammed. The tests were made on an oil pressure machine made by Prof. A. E. Wells.

To illustrate this point we give first in Table 1 a series of figures supplied by the Hunt-Spiller Mfg. Corporation.

Listed in Table 2 are 13 sands, tested green, whose cores have been broken with the dense side both on the top and on the bottom.

From Table 1 an average of 23.3 pounds per square inch difference is obtained. It is evident from this figure that to obtain the maximum strength from dry sand cores it is essential that the dense end of the core be placed upward.

Table 2 reveals a very slight difference in the two methods involved. It is conclusive from this figure that the core may be broken either way. But since the dry sand cores are broken with the dense side up, it would simplify the procedure to treat the green sand cores in a similar manner. Therefore, both dry sand cores broken on the Cornell dry sand testing machine and green sand cores broken on the Adams Green Bond machine will be tested with the dense end upward.

The chairman of the committee in order to try the sand himself asked for some of it and ran a series of tests, with similar

results to those obtained by Mr. Harrington of the Hunt-Spiller Corp. Thinking that the irregularity might be due to some peculiarity of the Wells machine he had some cores rammed up and baked, but these were tested in an Olssen compression machine. The results were similar and are given in Table 3.

Table 3

HUNT-SPILLER IRON FDRY. SAND—DRY BAKED 2 HRS. AT 150° C. TESTED AS RECEIVED FROM FOUNDRY.			
—Tested with Olssen 20,000-lb. Machine—		—Tested with Well's Machine—	
Dense End Up, Lbs. Per Sq. In.	Dense End Down, Lbs. Per Sq. In.	Dense End Up, Lbs. Per Sq. In.	Dense End Down, Lbs. Per Sq. In.
63	57	53	45
66	63	53	48
66	63	63	47
63	63	53	47
57	63	55	47
63	57	55	50
—	54	59	53
65	57	55	47
	—	—	—
	62	56	48
89	73	61	69
89	73	65	55
89	68	70	50
89	65	75	55
92	70	61	53
89	73	79	57
—	73	—	53
89.5	70	69	—
	—		56
	71		

There are two possible explanations. One is that the upper end of the core is rammed denser than the lower end. The other is that if the core is set in bake oven with top up as molded, and rests on a solid shelf, the top gets baked harder.

Baking tests made at Cornell, placing the cores in different positions, and supported on screen cloth does not seem to indicate that the trouble lies here. More tests are necessary to discover the real cause of the difference.

In conclusion the chairman wishes to express his thanks to the members of the committee who, without exception, have assisted in a whole hearted way in the committee's work, for it is to their labors that any results accomplished are largely due.

Respectfully submitted,

H. RIES, *Chairman*, Committee on Tests.

Report of Sub-Committee on Core Testing

To the Members of the American Foundrymen's Association: The sub-committee on core tests found itself with considerable uncompleted work at the conclusion of the Philadelphia Convention of 1928.

Having recommended certain changes in the tentative standard methods there remained the task of preparing the necessary data and drawings for publication of these changes in the revised sand test pamphlet, and also the study of the effects of some of the undetermined details and refinements of the test methods. The material for the test pamphlet was duly prepared through the cooperation of Messrs. Campbell, Dietert and Grubb.

The study of the effects of the details of the test methods and the determination of the proper conditions for maintaining the accuracy and dependability of the standard test methods was undertaken by the sub-committee members, and has proven a growing as well as an intricate problem. Progress is slow. Proper care must be taken to be certain of our ground and of the accuracy of our results when used as the basis for recommendations or conclusions and experience has shown that any attempt to rush the experimental work and hastily arrive at conclusions only leads to re-opening the subject.

The sub-committee held a meeting with the Technical Director, Dr. Ries, at Ann Arbor, Michigan, November 3rd, and made a survey of the problems before it. Both the uncompleted work and that covering new phases of core testing as yet un-attacked by the Committee, were covered and a program of future activities was mapped out.

It was decided to increase the personnel of the sub-committee to aid the prosecution of the work. New members have been added, with the thought of including representatives of the va-

rious branches of the foundry industry, as well as members who could aid in the study of certain problems.

The work now before the sub-committee may be divided into work in progress and future work, some already arranged for and some to be taken up later.

Work now in progress by sub-committee members

Details of Test Methods

1. Controlling Height of Test Piece in Tensile Strength Core Test.

This covers the relative merits of the use of a volume measure of sand cut-off to proper height after ramming (now the tentative standard method) and of a weight measure pre-determined for the particular sand being tested to give a core within certain height tolerances after ramming.

It also covers the effect if any of the disturbance of the surface sand by the cut-off knife.

2. Effect on Results of Allowing Cores to Stand After Baking and Before Testing, and of Re-heating Cores After Standing and Before Testing.

That cores should not be tested hot and that they should not be allowed to stand long enough to absorb a detrimental amount of moisture before testing is evident. Further, they should not stand too long after molding and before baking. The sub-committee is working up data to define the correct practice in these details.

3. Comparison of Tensile Tests on Tensile Test Briquette Machine and Transverse Tests on Campbell Transverse Machine.

Both these methods are now tentative standards. The sub-committee is still working on them to determine fully their good points and limitations and proper field of application.

4. Grips for Holding Tensile Test Specimen.

The proper material and design for the grips for holding the specimen in the tensile test have not been definitely established. Work is in progress on this item, the investigation including materials such as rubber, the use of rollers at the contact surfaces and the shape and contour of the grips relative to the specimen. On completion of the work, the sub-committee expects to recommend definite specifications for adoption as tentative standards.

5. Relation of Moisture Content of the Core Sand Mixture to the Strength of Baked Cores and Influence on this Relation of the Type of Ramming.

There is some evidence of a fundamental difference in the effect on core strength of the moisture content of the unbaked mixture, depending on whether the core is top-rammed by external means or is jolt-rammed by its own weight. This question is being investigated.

Permeability Testing

Progress is being made in evolving a simple dry sand (baked) permeability test to be carried out on the standard A. F. A. 2-inch diameter permeability specimen used to test green sand permeability. This should shortly be ready for recommendation as a tentative standard.

Testing Green Bond Strength of Low Strength Mixtures

The suitability of the standard compression test and of the tensile test for determining the green bond strength of low strength mixtures is being investigated to determine whether a special method is required for testing core mixtures of low green bond strength.

Standard Sub-Committee Test Methods

In order to insure that the test results obtained by the various members and used as a basis for determining standards, may be strictly comparable, and that they may be duplicated with reasonable accuracy by a careful investigator at any time, the sub-committee has drawn up a standard procedure for sub-committee tests. This thoroughly covers all details, such as kind and size of sand, use of distilled water, method of measurement, time of mixing and oven conditions and temperature. This procedure is now being discussed and criticized by the members and when generally approved will be published so that foundrymen may know the methods used in the investigations described.

Standard Sand

The question of a standard sand for core testing and especially for use in sub-committee tests has been re-opened. Arrangements have been made by the molding sand research com-

mittee for H. W. Dietert to prepare a quantity of Ottawa silica sand within definite grain size limits for the use of the members in committee investigations. This should aid in expediting some of the experimental work.

Oven Design

The importance of the type and design of the oven used in baking cores needs no emphasis. The members of the sub-committee have a great deal of data on the effect of oven conditions and design, on results. The committee on tests has recently suggested that the sub-committee outline the requirements of a satisfactory core baking oven and this will be prepared for publication in this year's Transactions. The sub-committee will apply these specifications to its own researches on core testing.

Future Work

The sub-committee has arranged for a comprehensive study of the compressibility or collapsibility of cores as affected by binding materials, and a considerable amount of work on this subject is scheduled for completion during this calendar year of 1929.

We also plan to take up the question of the measurement of gas evolution on which progress has been made by individual investigators and the measurement of surface hardness and its relation to permeability and to collapsibility. It is hoped by these various investigations to get at some of the perplexing questions about cores which daily confront the foundrymen.

Respectfully submitted,

E. R. YOUNG, *Chairman,*
Sub-Committee on Core Tests.

Foundry Sand Research Session

At the session on Foundry Sand, Dr. H. Ries presented reports as Technical Director of the Committee on Molding Sand Research (see pages 543-547) and as Chairman of the Committee on Testing of Foundry Sands (see pages 552-561), and R. F. Harrington reported as Chairman of the Committee on Conservation and Reclamation (see pages 548-551). Papers presented were "Some Experiments in Sand Control," by E. F. Wilson (see pages 183-198); "Some Factors in the Production of Sound Castings," by R. W. Kurtz (see pages 163-183), and "The Refractoriness of Foundry Sands," by J. F. McMahon (see pages 501-525). The discussion of these committee reports and papers follows.

DISCUSSION—REPORT OF COMMITTEE ON CONSERVATION AND RECLAMATION OF FOUNDRY SANDS

H. VROOMAN: What did those heaps consist of in which clay bond was used?

R. F. HARRINGTON: Some of the foundries reporting the use of clay bonds used sharp sand to maintain their bulk, and some used molding sand.

MEMBER: Is that bond added directly to the heap, or is it basic?

R. F. HARRINGTON: The reports from the foundries which I read indicate, as does my own observation in these foundries, that they are using clay bond, both in facings and in the conveyor systems.

MEMBER: Is it not a fact that the difference in the results obtained is due to a difference in the analyses of the clay?

R. F. HARRINGTON: I think, after hearing the reports of these various foundries, that we must conclude that all, with the exception of one, had eminently satisfactory results. As a matter of fact, they are using different clays; some are using two clays, some only one; there are, I think, four clays involved in the report I have read to you tonight, some from Pennsylvania, some from Illinois, and some from Wyoming.

MEMBER: I want to bring out the point that a deposit of clay may vary from one part of the deposit to another, and that might cause a difference in results at the foundry.

R. F. HARRINGTON: I would say that from our own experience and the experience of others, it would seem that the clay producer is doing a fairly good job in blending his clays, and I have personally heard very few complaints as to ununiformity, if I may use that word, in carload shipments. There have been some producers who have been criticized, but in general, I think they are endeavoring to produce a uniform clay.

H. VROOMAN: You have nothing from the foundries which used molding sand?

R. F. HARRINGTON: No, I don't think there is any one who would deny that there are foundries operating very successfully with molding sand. We have taken a few replies from a number of foundries representative of the automotive district in which very large tonnages are used, and also from foundries not manufacturing automotive castings, but which are manufacturing castings in quite different lines.

CHAIRMAN BULL: Of course, it is perfectly obvious, when you stop to think about it, that the molding sand committee has no measure by which it can comparatively determine the answer to Mr. Vrooman's question. In other words, take one foundry turning out a certain class of work, using molding sand without clay, and another foundry doing work of the same class; the committee is powerless to make any distinction as to the quality or cost of the work, except as it may get information direct from the companies concerned.

In the case of those foundries that have refrained from the addition of any molding sand periodically, one wonders how long it will be before they will have to change their practice, whether it is two years or three years, or some other period. It is a logical question to arise in one's mind, I think, and I presume that the experience that has been indicated to the committee is not such as to justify the committee in making any definite statements or predictions about that.

R. F. HARRINGTON: The committee can only take the facts as they appear to them, and I would like to take the opportunity at this time of stating that the committee has no brief for any particular phase of the situation.

H. VROOMAN: Mr. Chairman, you are a steel foundry man. Why is it you throw away your silica sand? Why do you keep buying new silica sand all the time?

CHAIRMAN BULL: In the steel foundry, we have a condition of fusibility which is extremely severe and is not paralleled in any other kind of foundry, and a good deal of our steel is poured from the furnace at a temperature around 2,900 to 3,000 degrees. I am speaking particularly of manufacturing small steel castings, where you have to have extremely fluid metal; the temperature is above that at which pure silica will fuse, and there is a certain amount of that sand that is deteriorated every time you use it. The result is that you have to add a certain amount of new sand to replace that burned out or fused sand, which will cause trouble if you use too much of it. There happens to be in this country very few sands which are usable in the steel foundry, which carry any appreciable amount of clay or bond. There are some in New Jersey, but the sands in the middle west are, for practical purposes, free of bond, so it is necessary in steel foundry work, to introduce bonds in the form of clay or other binders (clay of course being, for many years, the chief ingredient); but the average steel foundry buys its silica sand without respect to the bonding material in the sand, and a good deal of it will run about 98.5 per cent silica. Obviously that sand can not contain very much bond.

D. D. CAMERON: We use a 98 per cent silica sand. It has no bond; it is washed and graded. As to the chairman's statement that it is necessary to use new sand in steel castings, we have run for months and do not use it. We make castings up to 300 and 400 pounds, and we run day in and day out with the same sand, without any renewals at all. We take the sand that comes from the casting in our cleaning room, just as it is cleaned from the castings, as much as we can get off of it before it goes to the sand blast. That is all returned and goes back into our sand system again, and is used without silica renewal but with just a clay bond or another bond that we might select. We do not renew, probably, for months. We take Ottawa sand and wash and grade it to a certain mesh. Under a powerful glass it looks almost of one size. We renew with that sand if necessary, but we run for weeks and weeks without adding to our heaps. There is no loss unless some fuses enough to go to the sand blast. Of course, you lose that.

P. T. BANCROFT: I can not see that there is much of an argument here in regard to old sand and new sand. New sand is something that every casting has been made in, from the time that molding was starting, and yet it was not a new sand. It is almost impossible to make a casting with all new sand. I was in a foundry this afternoon where they had to use a base consisting of fifty shovels of old sand, three of new sand, and thirteen of silica sand. Now, when we reclaim the sand we have been hauling out on the dumps for years, that is something that an iron foundry man is interested in. We can reclaim sand and save a dollar a ton over the price of new sand. I know that, and if you want to make a synthetic sand, all you are doing is creating your old heap into a base sand, as I see it. Now I think we owe the committee a great deal of credit for the work they have done on this; they have devoted a great deal of time to it, and they have simply reported here what other people are doing.

There is no question but that you can run a foundry on new sand and probably show as good a profit as many who are reclaiming sand, if there is any economy in it. Those who want to do it can do it and those who do not want to do it do not have to do it. I can not see that there is any argument in this at all.

E. W. SMITH: What proportion of the replies was from steel and what proportion was from cast iron foundries?

R. F. HARRINGTON: The committee realized that the steel industry has always used a synthetic sand. It seems well to confine its investigations of progress to the gray iron foundry, so the reports I read were from the gray iron foundries.

E. W. SMITH: Our trouble in the cast iron foundry is that we use too much new molding sand. When you use too much, you put fines into your sand. You destroy permeability by using too much of new sand. It can be easily proven that if you have excess natural bond in your sand, it will invariably roll into little balls. You do not ordinarily notice them, but if you take a number six riddle, run some sand through and collect those little balls and grind them up, you can judge for yourself what you

have there. You have the bond in your sand, more than you need, and you are not using it. Then you blame your molding sand for not working. What is the answer? Find out how much bond you have in the sand and then go back and find out how you are using it. If you tested such sand as I mentioned, you would find clay, but half of it is in the ball form. The result is that your sand gets coarser, rougher. That is the experience in any gray iron foundry.

It has been customary to throw those tailings away. The man who riddles his heap after putting a wheelbarrow of new sand in it, I will venture to say, throws 25 per cent of his bond out in the dirt box. That is a strong assertion, but I am talking from experience, and the experience of most of us who allow the laborer or the molder to order sands according to their own particular whims.

If you want to fight the artificial bond, you must make use of the bond you have, and you won't have to waste any time saving the old sand that is going into the dirt box, because it is not a molding sand. Part of it is the residue from your cores.

MEMBER: I realize that there are only a few non-ferrous men here, but may I ask if any of those foundries that wrote to Mr. Harrington make non-ferrous castings?

R. F. HARRINGTON: They do not. No information was sought from the non-ferrous foundries. I think in another year, with the progress that has been made in the non-ferrous field and in the steel field, and I understand that there have been very definite changes in the steel sand program, the committee will possibly find it advisable to cover those three fields rather than the one.

L. L. ANTHERS: When you pour a large casting with a thickness of two inches, and it lays some four or five hours before shaking out, is not your problem one of revivifying?

R. F. HARRINGTON: I think it is. These foundries that reported were the largest in the country, and most large foundries, particularly automotive foundries, are operating with continuous systems and the sand does not stay in contact with the casting as long as it does in the ordinary jobbing foundry.

L. L. ANTHERS: Do you think, then, that you would have to add new sand in the foundry where you poured off a casting of two-inch thickness and left it in the sand four or five hours before shaking out?

R. F. HARRINGTON: I should say that you would have to increase the amount of bond you added. Whether new sand or clay bond, I would hesitate to say.

H. M. LANE: The question has been asked by some people about making heavy castings. About twenty years ago one prominent machine tool builder in this country making castings of the very heaviest sections, sometimes four inches of metal to be handled, employed dry sand which had a molding sand base, and they used their sand over and over with the addition of clay each time. The only sand that went into that mix was sharp sand. Now I know that that practice was followed for about ten years in one foundry, so it can be done.

H. VROOMAN: It seems to me that you are trying to make this sand game mysterious. There is nothing technical, nothing scientific, or nothing mysterious about molding sand. You buy molding sand for the purpose of renewal, and if you are running it in your shop on castings in which your sand in the heap would show, say 40 per cent bond, you do not want to purchase a new sand of a bond that is weak; you should buy a sand that runs 50 or 55 or even 60 per cent bond, and then your renewal would be less and you would not have to use clay, and in its introduction you would keep the coarseness of your sand at the same texture and you would maintain its permeability.

This question is simple enough. There is a minimum amount of bond that you could use with any heap on any particular kind of casting, and there is a maximum amount which you can use, and in between those two extremes there is a medium with a reasonable variation in which there would be no material difference in your losses. The only thing to do is to use a sand and keep your heap in condition.

The point for the foundryman is to buy, closest to his place of business, sand that he can get in at the lowest rates of freight. He can use it; the only question for him to find out is how to use it; and I claim that in all localities there is sand close to you that you can use just as well as you could if you went to New York, Ohio, or any other state for it, and paid high freight rates.

If you will buy a sand which will run not less than 50 or 60 per cent in bond, you will find that your renewals will be less, your castings will be as good and it will cost you less money than it will to use artificial binders.

DISCUSSION—SOUND CASTINGS

R. F. HARRINGTON: I would like to refer to the last sentence of the second paragraph on page 178. It says, "On the other hand, a sound top or cope produced without an extension head, is an indication of sound metal throughout." Do you mean to state or infer that if you had a casting forty inches in length and thirty inches in diameter, with an inch and a quarter section, and the top looked good, you would be assured that you had sound castings? That is a type of casting which in many instances I have personally viewed in our own plant and others, and it would under many conditions show absolutely no evidence of pull-down or anything of the sort, yet your shrink would be there; in other words, you have made instead of a casting forty inches long, one thirty inches with a ten-inch head on it.

R. W. KURTZ: We make a great many castings one hundred and fifty inches deep and we inspect more than the tops of them. In so doing we find that the castings whose metal exceeds $\frac{3}{4}$ inch in thickness usually permit evidence of any scabs, cuts, oxides, etc., to reach the cope surface before solidification. But while the top may thus be said to be a fairly good barometer of the molding practice, it cannot be relied on absolutely to disclose every and all types of defects. Mr. Harrington is correct in

his contention that shrinkage cavities are of the exceptional type in that they develop downward rather than upward and often leave no surface indication of their presence. In recognition of these facts, we cast feeder heads on our heavy castings.

A. C. JONES: Mr. Kurtz states in paragraph 3, page 176, that he uses large headed nails. I presume he refers to heavy sections. Has he had any difficulty in the machinability at some of those points where perhaps the steel nail was partly fused?

R. W. KURTZ: The truth of the matter is that I have never used one of those large headed nails in my life. I simply made the statement that they are used, so I am sorry that I cannot answer the question.

MEMBER: In regard to setting nails in castings, it has been my experience that it affects the casting very little except in cases where you are compelled to set nails at a point where the casting is to be drilled. In such cases, the variation in the hardness of the casting will cause the drill to run off. If your drilling locations are carefully avoided, when these nails are set, you will find no difficulty in the use of them.

MEMBER: Referring to page 167, items 2 and 3, in what particular respect do you regard the compression test on standard permeability specimen "inconvenient" for application to both mold and core testing?

R. W. KURTZ: A standard permeability specimen of baked oil sand core may have a compressive strength as high as 5,000 pounds. Suitable testing devices for strengths of this magnitude are elaborate and expensive.

There is, of course, a still broader indictment than inconvenience that may be had against all compression and transverse tests. The values obtained are entirely dependent on the shape of the test specimen. Actual failure is always by shear or tension or both. Compression and transverse tests merely introduce the complication of shape or form.

MEMBER: Will the gas pressure in actual molds in the foundry correspond to values obtained by your "blowability test?"

R. W. KURTZ: In actual practice, mold gas pressures do not depend solely upon the blowability value of the sand nor do uniform pressures obtain at all points on the face of the same mold. Other modifying factors are:

- (1) Degree of ramming and venting employed in making up the mold in question.
- (2) Size and shape of the casting.
- (3) Temperature and specific heat of the metal.
- (4) Temperature and specific heat of the mold.

The limiting blowability value of 10 grams per cubic centimeter stipulated for our sand is very conservative and with favorable modifying circumstances may be safely exceeded. In any case, such possibility is simply a question of whether or not the ferrostatic pressure can be maintained, from the start of the pouring till the metal solidifies, constantly higher than the mold gas pressure. Probably the most practical way of settling this

question is to cut away a portion of the cope of the mold so that the reaction to the hot metal may be observed.

DISCUSSION—SOME EXPERIMENTS IN SAND CONTROL

MEMBER: The author spoke of moisture in the sand. He mentioned that the more moisture, the more scrap. Does he refer to jolt molding, squeeze molding, or hand molding? There are three operations to consider. In my own experience, I have known of cases where we would take some sand on a floor, jolt it, squeeze it, and hand mold it. In the jolting we had scabs in our molds, in squeezing we had swells, and in hand molding we got our castings perfect. There was no difference in the sand whatever. What is the meaning of it?

E. F. WILSON: A question like that I will make no attempt to answer, simply because it is too inclusive. In reference to my paper, I am speaking only of our own practice, the only practice with which I am intimately acquainted, and possibly not as intimately as I should be at that. Our castings are fittings, etc., of the union type. They are rammed on the jolt squeeze match plate machine.

H. VROOMAN: Did you make your analyses before and after the sand became red hot?

E. F. WILSON: I did not.

E. W. SMITH: With reference to slagging material or so-called slag which did not originate in the cupola entering the casting, foundrymen know that if you have metal hot enough and fluid enough, and if there were any slag in there, it would be just like oil and water. They will not mix, and if gated properly, the slag will never reach the casting itself. You can take fluid slag and cold metal and mix them together and pour into a mold so that you will get slag into the casting. I am not talking about that, I maintain that if the metal is hot enough and fluid enough, you cannot put slag from the metal in that casting if properly gated.

Now I am going to ask Mr. Wilson if he knows the area of the opening of the runner into that casting, and its weight?

E. F. WILSON: I do not. I am not speaking of any specific casting, but am submitting data that cover the entire range of castings which we made, and the data have covered not one day but many days, and, in fact, years.

E. W. SMITH: The author has been through the same experience I have, but he formed a different opinion as to the cause. When I have observed pin-holes or slag-holes or certain kinds of shrinkage, I invariably find out whether the metal entered in sufficient volume to fill that mold rapidly. When I say sufficient volume, I mean not to fill that mold with such force as to tear it to pieces. Pouring through a hose-nozzle is the easiest way to describe it; if you are squirting a hose into the ground, you will tear a trench. Reverse the nozzle and you get the same volume but with less force. One great trouble is that we want to pour too hard. There is the tearing action which gives trouble. We often use too small a runner

in our desire to accommodate the chippers. That is a fault in every foundry, where in making a mold, we frequently skimp with space and cause trouble.

R. F. HARRINGTON: I think that Mr. Wilson is to be commended for having brought out some rather new ideas. We may not all agree with them; maybe we haven't thought enough about them to make much comment. Mr. Wilson is to be commended for having attacked these problems from a somewhat different standpoint. There is evidently absolutely no prejudice underlying his theories. That may be because as he has said, he has not been doing this kind of work for a great many years. H. W. Dietert has talked for a long time in regard to dry sand strength, and has declared that we ought to consider every green sand mold as a dry sand mold when it is being poured. In the same way, Mr. Wilson probably has hit upon a very worth-while thing in regard to this hot permeability. I never even thought of it before. I would like to inquire as to what was the temperature employed when he made his hot permeability test?

E. F. WILSON: Hot permeability is a theoretical thing I am setting up for somebody to shoot at. I would like to find out how to measure it myself. I think the nearest to it was the blowability test which was very excellently described in the paper just presented by Mr. Kurtz. I have made tests, however, by taking a sand and heating it to about 1,500 degrees Fahr. Of course, there is an ebullition of steam that can be readily measured. There is evolution of carbon dioxide. Now, the total of the volume of steam, plus the volume of gases from organic material, is, in one sense, a measure of this hot permeability. That is as near as I have come to trying to express this factor in a quantitative sense. It is rather at the present time a qualitative term, which I hope may be developed.

MEMBER: Do you have reference to a dry sand or a green sand mold?

E. F. WILSON: There is a hot permeability in both dry sand and green sand molds. In the case of a core, you can drive off all the gas, which probably will not amount to a great deal in terms of moisture, but may in the sense of carbon monoxide or dioxide.

R. F. HARRINGTON: Mr. Wilson, have you made any tests which indicate at what temperature this testing work should be done that would duplicate the temperature in the mold? Do you believe that the temperature an eighth of an inch back of the surface of the metal is up to 1,000 degrees Fahr.?

E. F. WILSON: That is something that is very difficult to determine. The nature of my work is such that I cannot put the time I would like to in the problem, which interests me greatly. I might try to determine the characteristics of sand in respect to hot permeability by using a manometer and pouring metal over the sand and gauging by pressure the amount of gas produced. The real quantitative concept of the thing is not developed as yet.

B. D. FULLER: Has the author taken tests of cold permeability and hot permeability from the same sample? In other words, has he a reading of cold permeability, we will say, from a core, and then a reading when the core is heated to 1,500 or some high temperature? If you have done that, did you find a wide difference in the two readings?

E. F. WILSON: I can only state again that the idea of hot permeability is not quantitatively developed. I have made some attempts at it, but those attempts have not been thoroughly successful, and that is why I do not present them here. I merely tried to present an idea that might lead others to follow up on this hot permeability. However, I have made tests for cold permeability, then determined the amount of gas which is given off of that same sand when heated up to 1,500 degrees. It is evident that there is a considerable difference in the permeability if gas has to be pushed through a sand specimen which contains steam and the carbon monoxide and dioxide organic material. The hot permeability of the sand may be extremely small, perhaps negligible. The gases may blow into the metal instead of passing out in the more normal way.

E. W. SMITH: I would like to ask the author how he came to study hot and cold permeability in the mold? It is rather deep for a foundryman.

E. F. WILSON: How I came to study the question of hot or cold permeability? Scrap.

E. W. SMITH: I will say amen to that. The question is one that concerns all of us; how to stop that scrap. Now, is it not true that your conclusions originated from a condition of your molding sand which caused blow holes in castings? That condition is caused by gases, no matter where they originated, no matter whether they are carbon gas or originated from the steam. Gases have no business staying in that mold while you are pouring. The permeability must be in the sand before you start pouring. I do not put a vent in any mold in my foundry. That is a broad statement. I do not use a sponge either, to create that gas, neither do I use a skimmer to skim off any of the slag out of the iron. I press my molds as hard as the mold will stand, because I want a true casting; but that sand must be open to allow any gases from that metal, or any gases from the steam, to be pushed out of the mold rapidly.

Let us imagine that a molder has to make a plate or a casting twenty-four inches square. If he will use a vent wire and will put four vents a second in that mold, you would think he was venting pretty fast. If he vented for sixty seconds you would consider that he was wasting time, but in that minute he will just put in 240 holes, which constitutes artificial permeability. I am to put in, before the molder gets that sand, 2,400 holes in that same place, and possibly a great many more.

If we use sea coal, we form a gas; if we put in bonding materials from our cores, a finer material than the sand itself, we fill in between those grains, we destroy permeability, and gas cannot get out of that mold. The result is that your casting is blown or scabbed on top. That is what caused you to study the difference between hot and cold permeability. I don't care if it is red hot or ice cold, as long as I have the permeability in my sand, I don't care what kind of gas is formed.

Two and one-half per cent is my limit for sea coal on ordinary work and five per cent on an extremely heavy casting. Twenty-five pounds of sea coal to a thousand pounds of sand means two and one-half per cent.

I have no trouble cleaning the castings, for that sand and other material, when it is made for a facing is absolutely, thoroughly mulled, riddled, tempered and revived, and it is delivered unhandled by hand to the molder to put on his casting.

R. J. DORY: I am going to agree with Mr. Harrington; Mr. Wilson has given us some new thoughts, particularly on hot permeability. I am going to follow them along a little bit and reap the benefit myself.

CHAIRMAN BULL: It is no discredit to Mr. Wilson or anyone else if he introduces more or less of an original theory and has not had the opportunity yet to produce quantitative results. I think a good many who are particularly interested in permeability will try to find out what there is in this idea of hot or cold permeability before the next convention, and have something more to say next year.

H. VROOMAN: I would like to know if the author carries out further his experiments in bringing sand to a red heat, whether he will get loss of bond? If he analyses his sand, are the alumina and silica practically the same before and afterward? My conclusion is that when the sand becomes red hot, the water of crystallization is given out, which leaves it without bond. It will combine with water afterward but will have no binding effect, because the heat has driven off this water of crystallization. If Mr. Wilson carried on this experiment, I would like to know his results.

R. MOLDENKE: The last remarks brought an idea to my mind. I always regret to see new terms introduced into the foundry vocabulary, such as "hot permeability" and "cold permeability." As far as I know, 1,500 degrees Fahr. will mean red heat; and the sand surfaces of your mold, against which you pour your molten metal, will seldom be red hot for more than a quarter of an inch in depth. Can't you keep the heat down to 1,000 degrees Fahr. instead of going up as high as 1,500 degrees, and thus get something valuable? If you go beyond the dissociation points of clay, the sand becomes worthless, and you cannot make a mold with it again. So you might run tests at 900 degrees or 950 degrees Fahr. and get some valuable results. If you use 1,200 or 1,500 degrees, you will get results that are useless.

E. F. WILSON: I will try to carry on some additional work on hot permeability and am very grateful for any criticisms which you may have. Dr. Moldenke has pointed out that possibly in the preliminary use of 1,500 degrees, we have used excessive temperature. That is probably a valuable suggestion. Until we have determined more about this, I do not think that any definite conclusions can be reached.

DISCUSSION—REFRACTORINESS OF FOUNDRY SANDS

MEMBER: In this question of refractoriness of sand, no account has been taken of the character of the sand so far as its co-efficient of expansion is concerned. That seems to be a subject that comes up in our work quite often. It appears that the characteristics of sand have been taken for granted and that some method of molding must be used to counteract the

tendency of various sands to expand as the castings are cooling. I wonder if all thought of that feature has been discarded?

J. F. McMAHON: We thought of that when we were considering different factors, but we did not feel that it offered such a physical change as was necessary to note in the investigation, and also that it be quite a separate investigation by itself.

J. F. HARPER: Has there been any attempt from a practical standpoint to correlate the sands that showed high value and low value in actual pouring conditions? In other words, some of those plotted lines ran into the iron section while others only extended into the non-ferrous section.

J. F. McMAHON: We received these sands from Dr. Ries and we did not know to what use they were put. I tried and Dr. Ries tried today to get the sands grouped and correlated and it will be in the final report of this paper.

MEMBER: I would like to have the speaker's comments on the action of molding sand that we have out in California. This sand forms a very heavy scale on the outside of the casting, but contrary to the general belief that such sand burns into the casting, while it adheres quite closely to the casting while the latter is hot, as soon as the casting is cooled off, the scale will come off very cleanly. The surface of scale next to the casting shows almost a fused surface. I tested this sand by making a cone an inch and a half in diameter and a couple of inches high, and put it in an electric furnace at 2,300 degrees Fahr. and it came out practically fused, while a cone of Albany sand similarly treated, while it showed the grain structure, was burned down almost completely. I have never had a complete chemical analysis made of that sand, but on the simple acid test, it does not show excessive carbonate.

J. F. McMAHON: It is not necessarily carbonates that are injurious. Carbonates are present, but your alkalis would be more harmful in this connection than your carbonates.

C. M. SAEGER: I only know of results along this line in connection with one of the steel companies outside of Philadelphia which is making a synthetic sand and using a bond of Bentonite. By the control of that Bentonite bond, they are able to establish a fluxing of that sand next to the casting, so that when the molders pour the metal, the steel immediately softens or sinters the sand next to the casting. When the casting is removed from the mold, the glass formed by heating the sand naturally chips off, due to the difference in expansion between the steel casting and the glass itself.

J. F. McMAHON: In the manufacture of enameled ware, it is one of the greatest troubles to keep the enamel on the steel or iron from chipping off. We have the same proposition when it comes to melted clay; you are trying to put a glass on iron. If you fellows could do that, you could make enameled ware without any trouble, and it is due, as Mr. Saeger says, to the difference in the coefficient of expansion.

Sand Control Shop Practice Session

This session on Foundry Sand Control was formed as a part of the shop operation courses and was primarily designed to bring out discussion on practical shop problems relating to sand in the brass, steel, malleable, and gray iron foundries. Four discussion leaders gave talks on the problems in the various branches of the industry. These talks and the subsequent discussions follow:

SAND CONTROL IN A BRASS FOUNDRY BY W. F. GRAHAM

W. F. GRAHAM*: In presenting a discussion of some aspects of foundry sand control, I recall a few memories of my first experiences in handling foundry sands fifteen years ago. The facilities available consisted of about seventy-five individuals of mixed middle European extraction, an old horse with cracked hoofs, a scoop, some sloping screens, a hose, and a remarkable collection of shovels. In the early hours of a winter's morning with a below zero wind off the lake, control was accomplished under difficulties. The testing was done in the fist and the technical terms used by the molding foreman in describing the properties of the sand the next day were often unprintable.

Now, sand conveyors, hoppers, revivifiers, and tempering equipment are common in many foundries. Tests are made by earnest young men of a scientific turn of mind and most any foundryman talks learnedly, if not discreetly, of tensile bond, permeability, grain fineness, and other of the mysteries.

Strange as it may seem, good castings have been and are made with sand control, without sand control, and despite sand control.

At the Ohio Brass Company sand control has occupied the attention of the technical and operating staffs in our several foundries for a number of years, and it is proposed to describe briefly what we are doing with

*Technical Division, Ohio Brass Co., Mansfield, Ohio.

the sands used on a sand conveying system which has been in operation for the past two years in our brass foundry.

In respect to grain fineness, our sands have been changed considerably within the last two years. The tabulation of Table 1 shows the trend towards a finer sand.

Table 1

CONVEYOR SAND				
	Grain Fineness	Clay, Per Cent	Bond, Oz. Sq. In.	A. F. A. Per- meability No.
1927.....	137	9.8	5.0	17.0
1928.....	166	10.8	5.5	13.5
1929.....	190	11.8	6.5	11.0

The figures of Table 1 together with the statement that last year we used 0.213 tons or 426 pounds of new sand per ton of total rough castings produced will give you, briefly, the governing factors in relation to our brass foundry sands.

The sand conveying and conditioning system serves fifteen molding floors and it has a rated capacity of fifty tons of sand. One man operates the system. His principal duties are to set the plows which fill the molder's hoppers and to regulate the water supply on the tempering belt.

Our testing program has been reduced to a weekly sample taken from the sand leaving the revivifier on the main supply belt. The samples are taken to our sand control laboratory and the determinations made as given in the previous table. The results of the tests are reported to the brass foundry foreman and the plant metallurgist.

Until recently, there were a number of sands used in our brass foundry. It was necessary to blend them in order to obtain a satisfactory molding sand, but for the last eight months we have standardized on a single sand. We are approaching the conclusion that for a given purpose, a single natural sand, if it can be found, is the best unless very extensive means of preparation are established for the blending of two or more sands or bonds.

The sand that we are now using has the characteristics as shown (Table 2) by the averaged tests on three cars.

Table 2

AVERAGE TEST OF THREE CARS OF SAND			Per Cent
On	6 mesh.....		0.00
	12		0.00
	20		0.13
	40		0.26
	70		0.66
	100		1.70
	140		1.90
	200		17.60
	270		9.20
Through	270 or pan.....		51.60
	Clay		17.40
Grain Fineness No. 242			

As the sand is used on the molding floors, it tends to run coarser and to counteract this, every day we add to the return sand conveyor three wheelbarrows of new sand in the morning and three in the afternoon. In order to evenly distribute this new sand addition, it is spread out over a period of one and one-half hours each time. If the weekly tests indicate that these amounts are insufficient to bring up the grain fineness, as much as ten wheelbarrow loads may be added in one day. In addition to these quantities, there is returned to the system from five to six wheelbarrows of reclaimed sand from the screen overflow, which has been mulled with about one-half wheelbarrow of new sand.

We believe that very little foundry trouble can be laid to our conveyor sand. However, in establishing this condition, several difficulties had to be overcome. First, we had an uneven moisture content due to condensation in the main hopper in cold weather, but this has been eliminated by the installation of heating coils. Second, there was a considerable amount of core sand returned which in the fineness test ran the percentage on the 70 mesh screen as high as 20. Third, the molding sand was contaminated by a very appreciable amount of metallics. These latter conditions have been corrected by substituting a vibratory screen for the original trommel above the main sand hopper.

While we may still be in the dark as to why is a molding sand and why some produce better castings than others, at least these methods of control seem to work out rather well in our brass foundry, to the satisfaction of all concerned.

MR. GRAHAM'S PAPER WAS THEN DISCUSSED

H. VRCOMAN: Do you make a distinction between clay and bond?

W. F. GRAHAM: The bond or strength was determined by the standard A.F.A. test, while the clay content was calculated from the screen analysis in accordance with A.F.A. methods. The bond or strength is a property; clay a material.

MEMBER: What is the average weight of your castings made in that sand?

W. F. GRAHAM: The exact figure for the total tonnage of castings was 0.93 of a pound. We make brass valves from a half inch to three inches, which includes various items of trim, trolley overhead materials, steam road electrification clamps and parts of that kind. Some of them run very light in weight. The heaviest casting is a large trolley frog or a three inch valve body.

H. J. ROAST: What is the tonnage of sand per day that you handle, roughly speaking? How small an amount of sand do you think it practical to provide such an installation for?

W. F. GRAHAM: The capacity of the system is rated at fifty tons, and I believe that includes all the sand in the molders' hoppers, on the belt and in the main hopper. It serves fifteen molding floors, and incidentally, it is running from thirty-five to fifty tons. The molders are taking all that sand.

R. W. JONES: Do you keep your sand in a storage bin for a certain length of time, for two or three hours, or keep using it over and over?

W. F. GRAHAM: The conveyor is started up in the morning with the molders' hoppers filled. Then a man is kept busy filling the hoppers. When the molders begin work in the morning, they use the sand in the hoppers above the molding machines. This is for continuous pouring in our brass foundry.

R. W. JONES: Is the sand shaken out and used again at once?

W. F. GRAHAM: It goes into a storage hopper. The turnover on the system is about once every hour.

D. B. HILL: How do you add new sand to the system? You add about five wheelbarrows of sand to the fifty tons of sand every day, do you not?

W. F. GRAHAM: As I said in the paper, there are three wheelbarrows added in the morning, and three in the afternoon, taking about an hour and a half for each such addition. A man shovels it in at intervals. Those wheelbarrows are all we add for fifty tons of sand, except when the grain fineness becomes coarse. Then an extra addition is made, but that is relatively infrequent.

H. VROOMAN: What do your six barrows of sand weigh apiece?

CHAIRMAN BULL: That is a perfectly proper question. I'd rather speak in terms of pounds or tons than in barrows or shovels of sand.

W. F. GRAHAM: I never weighed them. We have the total amount of sand used, per ton of castings. The wheelbarrow of sand, I imagine, will amount to forty shovels.

H. RIES: Mr. Graham, do you buy your sand on specifications?

W. F. GRAHAM: In determining the grade of sand that we want to use, we get samples from various sources of supply, make the various determinations upon them, and then as the sand comes in, we check it up and find out if it runs uniform. But as to our issuing a specification and then asking people to meet it, we don't do that. We check it so that we know it does not vary. If it did vary, we would, of course, object.

E. W. SMITH: Is your sand in constant circulation in a bin storage condition?

W. F. GRAHAM: A main bin feeds on to a tempering belt. The sand goes through a revivifier and drops on to a conveyor belt which provides the main supply. Fifteen plows on this belt feed the fifteen molding floors.

MEMBER: In controlling the tempering, is a standard amount of water introduced, or is the sand tested for the water content?

W. F. GRAHAM: It is tested by feel. It works very successfully, too. We have one man that does nothing else and we don't seem to have any complaints regarding variations in moisture content.

CHAIRMAN BULL: You don't maintain any laboratory method of moisture control?

W. F. GRAHAM: No, except for investigational purposes.

D. B. HILL: You said you have a bond of 6.5. What do you do when it gets below that? Do you add more new sand?

W. F. GRAHAM: I am very glad you asked that question, because I can tell you that we don't control by bond. We work entirely on the grain fineness.

CHAIRMAN BULL: Then the basis factor of your control is grain size. Is that true?

W. F. GRAHAM: That is true.

SAND CONTROL IN A MALLEABLE FOUNDRY, BY W. RANIS

W. L. RANIS:* Sand testing, whether conducted in a gray iron, brass, steel or malleable foundry, is essentially in technique and operation the same. It has come to the time now when we are practically all using standard A.F.A. testing equipment, and it is with such equipment operating in our malleable plant that we have received the following information and obtained the following opinions.

We are malleable foundry, melting about 100 tons of iron per day, and employing about 180 molders; differing from Mr. Graham's plant, we have no sand handling system. Each molder has his individual sand pile through which he works day to day, using about 85 per cent of the sand and having 15 per cent of cold sand left for him to start with after his heat the next day.

Practically all of our work is either vibrator plate work or matched patterns.

The demands that we have on sand can be classified into three groups according to type of work; first, we have our very small castings, which we make in a very light sand. Second, we have our general purpose sand for the average weight castings, which takes care of about 95 per cent of the molders. Third, we use a heavy sand for 2 per cent of our molders engaged in floor work.

It is about this 95 per cent of our demand on sand and tonnage that I shall spend my time discussing. The raw material or sand used for our general purpose work is a western Illinois sand of the screen analysis given in Table 1. That comprised the general purpose sand which we use in the greater part of our foundry.

Our sand control program from the beginning has varied a great deal from that which we have in practice at the present time. We have had sand testing with no control. By that I mean, we simply tested the sand, allowing the foundry to add as much new sand as it desired, as long as the sand was kept within the limits which were set forth.

Second, we had sand control or sand testing with absolute sand control. In other words, whatever the laboratory said was to go into that particular pile went into that particular pile, regardless of the protest set forth by the foundry.

The system that we now have in operation is sand testing with sand control, but with certain limits. If we find in the laboratory that the sand pile needs some form of new sand added, and the molding foreman ob-

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jects and says that the additional sand will cause excess scrap, we are willing then to have that question brought up for discussion between the laboratory and the molding foreman, and to then draw some definite conclusion as to what shall be done.

Table 1

Screen Size	Approximate Per Cent Retained
40.....	1.00
70.....	18.00
100.....	13.00
150.....	11.00
200.....	9.00
270.....	8.00
On pan.....	25.00
Clay.....	15.00

Our prime purpose in instituting sand control and sand testing equipment is to reduce scrap. Therefore, we are liberal at times with the foundry foremen, allowing them to bring forth their ideas, but we are constantly watching to see whether or not their predictions actually happen.

If we were to institute sand testing equipment in our plant at the present time, speaking from past experience, we would start about like this: we would buy standard equipment, and become fully acquainted with the methods used and set forth by the A.F.A. Then for a period of about three months we would test our sand piles daily for moisture, permeability and green sand strength. We would in no way attempt to dictate to the foundry what should be done. We would only be the silent observer of that which is going on. It is during this period that we would set forth and lay down the standard which we would attempt to maintain during our sand testing program. It is during this time also that those interested in sand testing should become thoroughly acquainted with the problems that are going to confront them, note the regularities and irregularities of the addition of new sand, and the difficulties that the molder is having with the conditions as they exist under the old system. Noting all the difficulties and comparing the sand conditions with scrap, we would be in a position to set the standards which we would use in our sand control program.

The standard for the general purpose sand which we are using in about 95 per cent of our jobs is: permeability from 18 to 28, moisture 6 to 8½ per cent, and green bond strength (by means of the compression apparatus) 2.8 to 3.3 pounds per square inch.

We found during our three months probation period that sand of those particular characteristics best suited our needs.

Our sand testing program is not instituted in the entire foundry. We have different programs going on here and there and different forms of testing going on here and there, but the program we are using to the greatest extent runs along about in this procedure:

The iron is poured into the molds between nine and ten o'clock in the morning. As soon as the molds are dumped and the sand placed in condition, the laboratory obtains a sample from the front, middle and back

of the pile, and tests it for moisture, permeability and bond, moisture by the rapid Dietert method, permeability by the regular A.F.A. method, and bond or green sand strength by A.F.A. compression apparatus.

If the moisture does not come within the limits which we have determined by our standard, the molding foreman is immediately informed that the moisture is high or low. Then it is up to him to correct it, if he sees fit.

The next variation is the bond or strength. If our strength falls below 2.8 pounds per square inch, new sand is added to that particular heat. If it falls within the standard range no new sand is added for that particular day.

The permeability does not change a great deal from day to day, but must be watched over a period of a week or more. If we notice that our permeability is gradually becoming higher or lower, we change that permeability. In case it is getting too high we change it by the addition of a sand similar to that in which small chain is molded or a sand that has a large amount of silt. If we are interested in opening up the pile we can do so by adding a silica sand with the grain size equal to the average grain size of the sand we are using, or we can raise the permeability by adding a new sand, which is of the open sand nature. We can add the silica sand alone but we prefer not to do this. It is better to add it mulled with fire clay or mulled with a new sand high in clay content.

Having determined that a certain sand pile needs new sand, the laboratory makes out a slip and gives it to the molder, who in turn gives it to the sand man. On that slip is stated the quantity and quality of new sand that is to be added. The sand man is anxious to get this slip because it is his means of being paid.

All sand is hauled on a piece work basis, and since it is hauled that way very few men receive sand that are not supposed to get it. On the other hand, the sand man is anxious to supply those who do need it.

The next step is to follow up all recommendations and make absolutely sure that the sand which has been prescribed actually goes into the pile. We found objections on the part of the molders to additions of certain sand at certain times, and they try their best to prevent such additions. However, if their foreman sees no objections, it is up to the laboratory or the person doing the testing to see that the instructions are carried out.

That in general comprises the daily routine sand test which we have instituted.

We also run dry sand strengths about once a week. We have found that certain jobs, especially, develop cracks. For a long time we laid the trouble to permeability and changed permeability from the high side to the extreme low side. Our latest clue along that line has been that our dry sand strength has been so high in several cases that when the casting set the sand failed to give way and developed a very small crack, which in annealing the casting, showed up more prominently, and, of course, resulted in scrapping the casting.

That is the reason we are testing once every week for dry sand strength. If our piles get beyond the working range, we can, by the addition of a sand which has a clay low in dry bond strength or high in dry bond strength, put them to the place where we want them.

Certain benefits that we think have been derived from this sand testing are: First, we have eliminated, to a great extent, the sand alibi. One of the easiest things for a molding foreman to say was, "Put in a load of new sand," and a great many times the trouble was remedied, but the cause may not always have been just the sand pile. An example of the need for their control is shown. We have a particular job in our foundry which develops scrap just as soon as we let the bond run down to the point where the average molder molded. Just as soon as we added a load of new sand everything went along very nicely.

Now, the problem there was that the pattern was at fault, and when the pattern was drawn we tore up a small amount of sand which, if the sand was high enough in clay content, the clay there would be strong enough to hold that sand from washing, but if the sand strength was not up to that point, it would wash and hence scrap castings.

Second, sand control gives uniform sand throughout the foundry. If you have a number of foremen, each foreman has his own conception of what constitutes good sand. By sand testing you get your foremen together and decide which sand is all right, and then you institute that same form of sand throughout the entire foundry.

Third, we find that the program is very educational, both for the molder and the dumper. We find that we are getting better results because we are checking.

Fourth, it offers the purchasing agent a means of checking by tests the new sands coming in. If the sand works successfully, the purchasing agent, informed of that, knows that the sand he is buying is the sand that is desired by the foundry.

We have improved certain conditions during the years of sand testing which we cannot directly say we brought about because of sand testing alone, but which show at least that it has done nothing to hinder the progress of the foundry. That is, we have increased the hourly production of the molder, we have increased the net good castings, and on the particular area, on which we have concentrated our sand testing, we have decreased the scrap. The area referred to was chosen because it was the highest scrap area in the plant. We have never been able to get it to the lowest scrap area but at least it is no longer the highest scrap district in our foundry.

THE PAPER BY MR. RANIS WAS THEN DISCUSSED

N. M. WATERBURY: Noticing the difference between the methods of sand control in malleable and brass foundry practice, as described in the papers, I would like to ask Mr. Ranis if he pays any attention at all to grain size so far as control is concerned?

W. L. RANIS: In our particular case, we pay very little attention to the grain size in the sand heap from day to day. We control that entirely on our day to day analysis, by permeability. If our permeability is as we want it, we pay very little attention to grain size. We pay attention to grain size when we buy new sand. We are careful then that the grain sizes are as we want them. Having purchased sand from the same producer for a number of years, we know the sand purchased from him in the raw state comes close to the average analysis which we have, so that we don't have to worry about grain size from day to day.

CHAIRMAN BULL: You feel, then, that dependence on one reliable source of supply automatically controls the grain size proposition, to a considerable extent?

W. L. RANIS: Yes.

N. M. WATERBURY: I might add to the discussion of sand control in malleable foundries by stating that the plant with which I am connected melts probably 120 tons a day, and about 40 per cent of that tonnage is in a part of the foundry where the sand is handled on a system for sand conveying and preparation. We have installed a certain amount of sand control in that system rather than in the part of the foundry where the sand is in heaps. When we first started out, the idea was that we should work on grain size. We wanted a certain definite finish on those castings, which average a half pound or under in weight, and we thought that by having proper grain size we would be able to keep the finish at a highly satisfactory point. We found the grain size did not answer for this purpose at all, because we found a sand which had the bulk of the grains on one screen, when we came to average it, would have the same A. F. A. grain size as another sand which had no predominating grain size with the sand distributed fairly well over a great many screens. We had to drop the grain size proposition. We have not forgotten it entirely, but it has not worked out very well as a sand control medium.

We substituted permeability for grain size as a control. Permeability does not change rapidly in our system, but we can watch, as Mr. Ranis said, the tendency to change, and correct it. We are in the same position as most any other manufacturer making small castings, in that the core sand is coarser than molding sand. In order to overcome the coarsening effect of the core sand additions to the heap or system, we have found it necessary that the new sand we add be very much finer in grain size than we expect the foundry heap to average.

MEMBER: I understand that you raise your bond strength by the addition of new sand. What effect would this addition have, if it were natural clay?

W. L. RANIS: We add new sand for two purposes, one purpose being, as I stated before, to increase the green bond strength of the pile, and the other to keep the pile up to the quantity that we want from day to day. A certain amount of sand adheres to the castings, and that is thrown aside and dumped alongside the molder's floor. It has been our practice whenever possible, to take that sand over to the muller, and mull it up with new sand or with fire clay. We have no great objections to fire clay.

We have run tests on fire clays and Bentonite binders having various trade names for a series of months. If we were to add clay we would much prefer to do it by mulling it with some other sand rather than putting it into the sand heap alone. Some of that colloidal clay is almost like dynamite, and you have to be very careful how much you add.

MEMBER: Mr. Ranis, referring to your statement regarding the dry sand strength being conducive to hot tears or checks, what dry sand strength would you say would cause this, and what method would you take for correcting it?

W. L. RANIS: The particular job I had in mind was an elliptical job, which was very thin in section. I will have to use the shear test data in pounds per square inch in speaking of that job because the problem confronted us before we adopted the compression test.

We had two molders running the same job day by day, and one molder was getting scrap from cracks while the other man was not. We reversed the patterns and it made no difference. The same man got scrap. We then changed the molders to different sand piles, and still we got scrap. So all we could say was that it was in the sand. The sand which gave no scrap showed a dry strength of about nine pounds per square inch on the Dietert shear test. That which developed cracks showed seventeen pounds on the Dietert shear test.

One furnace was not operating for a while and we dumped a bunch of Albany sand in this area. When we were about to start the furnace we collected a lot of that sand that had been on the floor. This particular pile had as its base a good deal of Albany sand, and that particular clay appears to have a low dry strength, whereas the sand we are getting from western Illinois has a very high dry strength.

Another thing about Albany sand, it appears that a per cent increase in moisture does not seem to affect the dry sand strength nearly as much as a per cent increase in moisture would in the western Illinois sand.

E. W. SMITH: Does not the addition of binders, clay, Bentonite, etc., make the grain size of the sand smaller?

W. L. RANIS: In a group of tests that we ran, when we used these various materials, we could not find any decrease in the permeability. However, I do not claim that these additions will not decrease the grain size. Some of the refuse sand off the floor, because of its being close to the castings, has been fused, and the average grain size of those particular particles may have thus been increased, prior to introduction into the heap. That may have been the reason the permeability did not decrease.

MEMBER: As I understand it, you have 180 molders. How many floors have you under control?

W. L. RANIS: I made the statement that our entire foundry is not under sand control. We have a certain section that is under the control that I mention. We have another section of the foundry where we try out different things.

MEMBER: How many men are needed for making control tests?

W. L. RANIS: One. An element that comes in is that of time. We have recently made our compression tester operate by means of an electric motor, with automatic switches. The motor starts just as soon as the specimen is in; when the specimen breaks the carriage automatically goes back. At the same time, there is an automatic recording device which tells where that specimen broke. That is saving us at least one-third the time.

S. H. CLELAND: Would the continued additions of fire clay having high dry bond value, which would harden at low temperature, cause the cracks you mentioned?

W. L. RANIS: I would not be in a position to say just what the condition would be as to that fire clay. I have not worked enough with the fire clay and that special problem has never come up in the heaps in which the fire clay has been used.

S. H. CLELAND: If I may venture the opinion, based on experience, fire clay of that character would cause cracks. The secret of success in using clay bond is to employ one that will provide soft sand next the castings. Such a sand would give freely as the castings shrink and cracks would be obviated.

H. L. MCKINNON: In these tests was any attention paid to the refractoriness tests on the bonding material in the sand? The reason for asking this question is that in a malleable plant of which I have some knowledge, it was found that the sand with a fusion point around 2400 degrees was not satisfactory. The sand rapidly deteriorated. By getting one that had a fusion point around 2600 degrees, this was overcome. I would like to know whether the author has made any analysis along that line to see whether or not his bonding material had head resistance enough to withstand the high temperature.

W. L. RANIS: We have never done anything directly with fusion point. Whenever we look into the problem of a new sand we would experiment more in the way of a life test, which is a much slower proposition. We take a new sand and run the bond strength on it, and then pour so much iron into it and run the bond strength again, then pour so much more iron into it and run the bond strength again, and see how many pounds of iron it takes to bring it down to a certain bond strength. Then we compare that with the sand we have had before, other things being equal, that is our method of determining the life.

CHAIRMAN BULL: You feel perhaps that the fusion point of your sand is indirectly indicated, by the condition of bond that remains after continued use?

W. L. RANIS: You can answer that question yes or no. You can tell a lot as to the fusion point of sand by the general appearance of your casting. If your casting comes out reasonably clean you would say that the fusion point of your sand is somewhere within the limits you want. If a lot of it adheres to the casting and the casting is measurably hard to clean, so that the cleaning department objects, then you can directly say that your fusion point is too low, without running any test on it whatsoever.

Another thing that will usually show up is when you make your life test, as we do, for the life of the bond, see how much of that sand adheres to the particular casting that you make. That will give you some indication.

E. W. SMITH: Mr. Ranis stated he took a western Illinois sand, which is very peculiar to me. Sands of the Rock River district are noted for their lime content. Have you tested your sand for lime?

W. L. RANIS: Whenever we go into a new district, or attempt to look for a new supply of sand, that is about the only time that we run a chemical analysis on that sand, and we have run chemical analyses on this particular sand. Our belief is that as long as we keep the total of the calcium oxide and the magnesium oxide below 5 per cent, we don't have any trouble. Above that we do have trouble. I would say the sand we are using runs below 5 per cent total calcium oxide and magnesium oxide. The percentage, I can't tell you. When this percentage is exceeded, it means trouble may result and for that reason we have established that as a maximum. That is one of the things we look into when we search for a new supply of sand.

W. A. JANSSEN: In answer to Mr. McKinnon's question and also the question of Mr. Smith, I would like to mention a bit of experience which might be of interest. A year or more ago we had occasion to make some malleable iron in an electric furnace. Rather than use a silica sand such as would be used in a steel foundry for making the molds, we used a loam used in the malleable foundry. Our only thought in making the tests was to see how close we could control our malleable mixture in the electric furnace without any regard as to the appearance of the casting. Our thought was that the loam would be "burned in" because of the low refractory value. To our very great surprise, we never saw cleaner castings. I am not decrying the value of sand control, but we must also give some thought to the cleanliness of metal and its influence on some of the constituents of the sand, having in mind particularly that if we have a metal which may be high in oxide, when those oxides come in contact with certain definite proportions of, we will say, clay or other fusible materials, they may set up a eutectic of lower fusion point which would be the cause of the "burning in" rather than the particular quantity or quality of those constituents in the sand.

W. F. GRAHAM: I would like to ask Mr. Ranis what relation there is between the grain size of core sand and the grain size of molding sand. If the grain size of core sand is much coarser than the grain size of molding sand, how does it affect the permeability?

W. L. RANIS: We don't use any one special kind of core sand. We employ various mixtures in which we use a fine grade of silica sand, Michigan City sand, and local sand for giving us our green sand strength. With all those varieties in the mixtures, I cannot answer your question.

W. F. GRAHAM: With the addition of that silica sand, permeability is made much higher than that of molding sand. Will that not increase the permeability of your heaps? Silica sand even of very fine grain has very much higher permeability than molding sand. To offset that you would have to add a great deal of fine molding sand, would you not?

W. L. RANIS: We find it very easy to close up a pile. This is about the easiest thing you can do to cut down your permeability. But if you want to open it up that seems to be harder. Our particular problem is usually to prevent closing up the pile.

As I say, we have run along now for possibly six months without a great deal of worry about permeability. It has kept within range. The thing you want is to know what your operating conditions have been for a number of months, and then choose your new sand in such a way that even though you are having a certain amount of core sand coming in, the new sand which you will add will be of the proper nature to counteract that.

N. M. WATERBURY: I think perhaps Mr. Graham's question was prompted by my remark concerning the core sand which enters our sand system. We have a system at the Link-Belt Company in Indianapolis that has core sand going into it. It is Michigan City sand. If no effort were made to counteract that, it would increase the permeability value, perhaps, as high as fifty, whereas twenty to twenty-five is desirable. In order to prevent that, the new sand, instead of being the fineness which we would use, is much finer, and at the finish we get a sand we consider good.

R. J. DOTY: In my experience, I have found that it takes a vast amount of coarse grains to materially affect the permeability of fine grain sand. You can change the grain size rapidly, but you can't affect the permeability very much by introducing it. The theory I have is that the small grains fill in the voids between the large grains which brings about little, if any, change.

SAND CONTROL IN A GRAY IRON FOUNDRY, BY R. F. HARRINGTON

R. F. HARRINGTON:* I have been asked to talk for a few moments, in a very informal way on Sand Control in the Gray Iron Foundry.

As I view the situation, sand control in any foundry, iron or otherwise, presupposes certain definite things. It presupposes a knowledge, first of all, of the raw materials that we are concerned with, molding sand, core sand, sea coal, clay.

It presupposes a specification for those commodities, a specification based either upon the A. F. A. methods, or the so-called sample method of specification, whereby a sample is submitted to the producer and he is asked to match that sample. With such specifications established, it is the concern of the test department or the metallurgical or sand testing department to see that the incoming raw material meets up with either one of these specifications, either the A. F. A. specifications that may have been set forth as to grain structure, as to clay content, etc., or to see that the sand as shipped in measures up to the characteristics of the samples that have been submitted.

Either method, I believe, is entirely practicable. The sample method, I think, permits of a little closer relationship between the producer and the consumer, and I urge the foundrymen to get closer with the producer of his raw material, go to the banks, if you will, visit them, see the conditions

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under which the material is produced, and obtain an intimate knowledge of the producers' problems.

The same thing, I think, applies in the case of our clays, our rebonding clays.

In connection with the incoming new molding sand, personally, I don't think we are concerned with the permeability. I think we are concerned with the moisture content, the grain characteristics, and the clay content. We are more concerned with what the effect of that molding sand will be when it gets into the heap. That is where we are interested in the question of permeability, not what it is in the raw sand as we receive it.

In the case of the clay so many of us are now using for rebonding, we are interested in certain characteristics in that connection. There are many and varied tests that are applied in the case of the clays, some of them very simple, indicating certain definite characteristics.

The work of our A. F. A. Committee on Sand Tests has been to develop intelligent methods to compare the value of one clay bond as compared to another. You will be told when this year's reports are presented that there is much yet to be done in that connection, so I will not comment at great length on the question of testing these clay bonds.

It is a fact, however, that there are a number of foundries which have established certain very definite methods that permit them to determine the relative characteristics of these clays.

Now, we have the question of sea coal. I think lots of us are missing a good bet when we don't know more about our sea coal, because it plays an important part in the making of a mold when we produce a sound casting. The grade or grind of sea coal is distinctly important. If some of you have any doubt, let your purchasing department by error order a fine grade of sea coal, when your molding department is expecting to get a coarse grade.

Consideration ought also to be given to the question of the value of that sea coal in regard to the volatile matter and in regard to the ash content. Particularly is it important to know the effect of a fine sea coal in relation to a coarse one. A fine sea coal in any molding sand heap will detract distinctly from the permeability of that sand.

Molding sand control in a foundry, I believe, presupposes a knowledge of the condition of the heap or of the facing if we have previously set up a standard. If we follow that standard as to permeability, strength, and moisture, we know that we produce or can produce good castings, other factors normal.

Depending upon these characteristics of moisture, of permeability, of strength, the foundryman has a right to expect that those are maintained properly for him, and I believe it is the duty of that department in the foundry that controls those matters of permeability, those matters of strength, and of grain structure and moisture to keep the foundryman fully informed, because I must admit that with the introduction of clay bonds and the conservation programs that are going on in our foundries today, many of the practical foundrymen are almost helpless. They have given up long ago attempting to predict that a certain sand, because it feels this way

or that way, will or will not do the work. So it is up to the department carrying on the investigative and the sand control work to keep the foundry department closely advised and work with them to the fullest extent.

I believe that it is a distinct advantage in every foundry to have the control of the molding sand, which has now become such a matter of technical importance, under the control of a definite head or a definite organization in exactly the same way that your metallurgy or your heat treatment is under that control. But we must remember the contact between the foundry and the test department or the control department must be unusually close, because we have so much to learn in relation to these factors that in the past have caused the foundryman his grief, and we have to tie up some of those factors with some of those problems with the material we now have to work with in the way of knowledge of permeability, of strength and of moisture.

One reason why we as foundrymen had to get away from the feel method of testing sand was because every fellow's thumb was not calibrated the same, and we could not interpret in mechanical terms the condition of the sand.

In the same manner that the foundryman can properly expect full co-operation upon the part of the organization handling the sand control and sand research, so should the control department or sand testing department, expect the fullest co-operation upon the part of the practical man. It is useless to put into the foundry a sand that may have been ever so carefully designed as to its characteristics, and then have it maltreated in the foundry. There are hundreds of tons of defective castings, in my opinion, that result not because the sand went into the foundry in a poor condition as to mixing or improper physical characteristics, but because that sand that was right, so far as its physical characteristics go, was maltreated.

For example, if you are using jolt machines you have to know that that sand is jolted a definite number of times as determined by the permeability and the strength characteristics. The ramming cannot vary from day to day. In order that the final product which we are after, and that is a good mold, may be uniform every hour of the day, and every day in the week, and every week in the year, it requires the closest of cooperation from the standpoint of the foundry. In some foundries the control of the number of jolts is definitely linked with and made a part of the sand control, in order that these factors may be more closely connected.

We talk about poor flow in sands. We have a distinct problem there. The man that can help us the most in it is the man out in the shop. We cannot afford to put out in the foundry a sand that does not flow well or that does not jolt well, because that means a mold that is harder on one side or the top or bottom, than in some other place, which will result in strained castings.

I believe there is a distinct advantage in a study of the finished mold. I have seen a great many sands blamed for a trouble when it was nothing but a pattern situation. One example was a case of a mold with three gates, one gate improperly arranged, so that it had a nozzle effect, causing the

shooting of the metal off to one side of the mold forming a scab or buckle on one side. Every time that casting was defective it was defective in the same place.

I am going to conclude by suggesting that any advance that we have made in the past has been through the distinguished work of our A. F. A. committees in the development of standard tests that allow us to talk the same language. The advances that have been made in conservation programs throughout the country have been based solely upon the knowledge of the molding sands, of the heap sands, of the facings that have been obtained through these tests, and any advance that is to come in the future is going to come with increased knowledge of our methods of testing with intelligent application of them, with thorough co-operation between the development, research department or control department, so far as the sand pile goes, and that will mean just one thing, a higher quality casting produced more economically.

MR. HARRINGTON'S PAPER WAS THEN DISCUSSED

H. W. DIETERT: Do you use a combustion or nitric acid method of determining the sea coal?

R. F. HARRINGTON: Frankly, we have not developed a satisfactory method for measuring sea coal content in heap sand or facing sand. It is regrettable and is one of the things that must be worked out by our A. F. A. committee.

CHAIRMAN BULL: Do you have moisture control as one item of your daily routine tests?

R. F. HARRINGTON: Yes, we do.

CHAIRMAN BULL: Permeability and strength also?

R. F. HARRINGTON: We make tests for permeability, moisture and strength, every day, on every heap, and sometimes more than once a day.

CHAIRMAN BULL: How often do you run screen tests?

R. F. HARRINGTON: We run screen tests if we are going over onto a new sand and on new development work, sometimes two or three times a week; ordinarily once a week.

CHAIRMAN BULL: How about ignition loss to get an indication of fusibility?

R. F. HARRINGTON: I quite agree with the former speaker that the best answer for fusibility is to go out and look at the castings in the cleaning room.

A. E. HAGEBOECK: Which strength test do you use?

R. F. HARRINGTON: The Cornell compression test apparatus.

R. W. JONES: Do you make the same castings day in and day out?

R. F. HARRINGTON: Generally speaking, the castings are the same as to general character, varying little in weight.

R. W. JONES: Don't you think you would find a difference if you had to make different castings in the same heap different days?

R. F. HARRINGTON: Naturally, the problem would be more complicated.

R. E. BRYANT: I was interested in what the speaker said about fine sea coal. I was wondering whether the effect he mentioned was solely one of silting or whether he had in mind a variation in the burning with fine sea coal as compared with coarser?

R. F. HARRINGTON: I believe you used the word silting effect. That is exactly the effect I had in mind.

A. C. JONES: I would like to ask Mr. Harrington in regard to the matter of standard jolting, what his range in permeability would be between a condition of flowability of sand that would cause a strain in one case and cause a scab in another section of the same mold?

R. F. HARRINGTON: That brings up the question of mold hardness, and I should say that a 5 per cent variation in mold hardness would be the difference between a good casting and a bad one. Now, measured in terms of jolts, if a jolt machine was jolting fifty times, sixty jolts would be possibly productive of an improper mold, so far as hardness is concerned. It is that closely in balance when you are operating with a clay bond.

I might add, with different heap sands and with different new sands or clays constituting that heap, that fact is different. In other words, you may have a wider spread in one case or a wider limit.

THEORETICAL VS. PRACTICAL STUDIES OF FOUNDRY SANDS

BY E. W. SMITH*

For over fifty years sand used for the making of molds to receive molten metal forming the millions of tons of castings used in the industries and arts of the world has been the object of intensive study, apparently from two angles. That of the scientists and research men connected with many universities, colleges and schools; and on the other side, that of the practical foundrymen of the world and their molders.

Looking to the past, it seems there has always existed a well defined separation between them. An excellent example of this was shown upon the entry of the use of chemical analysis for control purposes in cast iron forty years ago. Many of our older foundrymen will recall the satirical references to the "rule of thumb" practice of that period. As a matter of fact, good castings were made and books were written on foundry practice many years before the advent of the chemist into the foundry, an illustration being "Molders & Foundries," written by Fred Obermann in 1852.

The so-called "rule of thumb" represented a practical operation of physical analysis and determination of the grades of metal by the fracture and depth of chill markings of the pig iron when broken, carefully separated into different piles as graded, the grades ranging from Numbers 1 (gray) to 5 (white iron). Special charges were made, carefully recorded, results kept for future use, and the methods followed would bear the same relation to

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present day melting methods that gravometric analysis bears to volumetric analysis. Equally as good or accurate results could be obtained by the use of either.

There is no question whatever in regard to the excellent results in metallurgical progress attained by the foundry chemist in the study of metals, but progress in the use of the chemical analysis of "sand" has not kept pace. There appears to be no connecting link between the analysis of sand made, and the foundry application to secure reduction of losses. The writer has had access to the analysis of different sands for over thirty years, but there does not appear to be any means of connecting them with the foundry proper to reduce losses or prevent them. At one time many of our larger foundries issued special chemical specifications for the purchase of their sands, but any recorded information of scrap reduction never has been given out.

There has been but little change in the study of molding sands since the earlier writings of Doctor Moldenke, T. D. West, J. W. Keep and A. Sorge, Jr.

Bond was determined by the use of an oblong bar of sand pushed across the edge of a plate until the overhanging section broke off. The length of the end broken off was measured and recorded for comparative strengths.

Permeability usually was determined by the blowing of smoke through the sand in testing cores, etc.

Strength and Moisture generally were determined by "feel" plus the experience and judgment of the man most interested, the *molder*, upon whom is placed the blame for the losses which occur, regardless of what forms of tests are used or by whom made.

Surface Finish of the castings was predetermined by the fineness of the grain, by "feel" only; that also was a determining factor of the permeability.

It would appear upon reading the foregoing paragraphs that the foundryman and the molder had everything that they needed to produce good castings as far as the sand requirements were concerned, but there was and still exists a great drawback, namely, the lack of a common language by which the molder or foundryman could convey to the purchasing department or executives, and they in turn could inform the producer of the exact material needed.

Sand usually was shipped as selected according to the "run of the pit," which experience has shown varies greatly in both texture and strengths. This made it extremely difficult for the man in the foundry to obtain uniform results, and often resulted in unjust condemnation of good materials and undeserved discredit to the producer. It must be said the sand producers tried to conform with the requirements of the foundrymen, at the same time keeping in close touch with those engaged in research. The latter made it extremely difficult at times on account of the many changes in standards of selection and test methods. Some of the larger producers have gone to extreme lengths and considerable expense in providing improved production machinery for creating a more uniform material. The period from 1923

to 1928 was one of unusual activity in sand studies and interest taken by our universities, colleges, sand producers, chemists and foundrymen.

Numerous papers have been discussed by technical associations and clubs. An enormous amount of research work has been accomplished featuring the structures of molding sands and their characteristics, physical and chemical. This work has also resulted in devising test methods for determining the sand properties; some of which tests have been extremely valuable to the foundry work even if they did nothing more than to attract attention to the fact that sand was an important factor in making a good casting. But strangely absent from all which has been said and done is the question of scrap losses in the foundry and how far the sand or treatment may be held responsible and why?

It seems some of the money and time spent in research could be devoted to this phase of the sand question. Those who have been benefited most by what has already been done are the foundry engineer, and some who are commercially interested. The man in the foundry has been kept going in circles trying to keep up with the many new theories, materials and devices offered. He does not turn to them unless troubled by excessive losses.

Every practical foundryman knows when his sand is *too* wet, that being one of the first things taught him when starting out. He knows what happens when he pours hot metal into it. The moisture test is useful only where large bodies of the material are tempered continuously as for continuous melting practice, and not even then if the tempering devices are properly devised.

Permeability tests are useful only to the sand engineer in testing "new" sands and in the study of artificial blending of different sands by those interested commercially. The practical foundryman knows that his sand must be sufficiently open to allow free escape of the gases from the mold.

The permeability of a sand while in the raw state has very little relation to the heap, as used by the molder, after running the gauntlet of hot metal. Ash from seacoal and other materials, with silt and fines from the destruction of the bond, whether natural or artificial, fill the spaces between the grains and destroy the permeability. After the novelty of the use of test methods wears off, the foundryman's interest gradually ceases and he returns to the old stand-by, the scrap-pile, and investigates the individual heaps to find out why, if the sand used is up to the proper standard, some heaps are more productive of loss than others.

Fineness tests are useful only in determining the fitness of the sand for the character of the work to be made, and the surface finish desired.

Clay tests are also largely for commercial purposes. The clay content in any heap constantly is varying as affected by the weights of the castings and varying burning out process. Clay tests are useful also for laboratory purposes in the study of the component parts of the material.

Clay necessarily does not indicate a suitable bond as understood in foundry parlance. This may be understood better by considering a clay test of a *strong bond* molding sand. When the clay has been all dissolved and washed out of the sand by the sodium hydroxide solution, then the

sand thoroughly dried and tested for fineness, a portion will be found to have passed through the 270-mesh sieves. This material is fine enough to be colloidal, but is not a true colloid, yet this material is necessary as a distributing medium for the clay. This is the vital requirement of any so-called artificial binder.

Bond study to be of any value to the man in the foundry should be of the heap sand, and daily. Bond is by far the most important element affecting the production of good castings. If it is in excess in the heap when used, scrap will surely follow. Also, if the heap is deficient in bond, scrap will result. The percentage of bond in a heap should be taken only *after* all new sand of the day has been added. This gives the bond content of the sand for the succeeding day and an advance knowledge of any necessary increase or decrease of new sand needed. A predetermined bond figure must be arrived at as a base for bond control. This figure may be determined by testing the sand each day for several weeks.

Make a graph of these tests on horizontal lines, with each of the spaces between the lines representing two per cent. Vertical lines and spaces should be dated across the top as working days of four weeks. Vertical spaces should be numbered from bottom to top 20-22-24-26, etc. The percentage of loss from the corresponding dates is marked across the bottom. When a two weeks' graph has been completed, a line drawn through the center will indicate the predetermined bond figure. If this figure is found too high or too low, and scrap is excessive, it is easy to change it for stronger or weaker sand as the scrap trend indicated.

If the calculation has been made properly, a variation up or down from this figure "four per cent" should not increase loss, but if the test shows over four per cent, scrap will surely be caused by too strong sand. If under four per cent scrap will be caused by too weak sand. This allows a safety factor of eight per cent within which to control the bond in the heap. Say that the predetermined figure calls for 40 per cent bond required, 44 per cent will not create loss, 36 per cent will not create loss, and if the determinations have been made accurately it is possible to have an entire month when the bond does not vary two per cent, then all other sand conditions being equal the scrap should be at a minimum.

To work out this method in any foundry may at first appear confusing on account of shop conditions which seem to interfere, but it will simplify itself very quickly if carefully followed out and if variations in losses each day are compared with the bond percentage.

In initiating such a program make no change in the *new sand*, from that which has been regularly used, until changes are actually proven necessary. Classify the work being made into four divisions—Light, Medium, Heavy, Extra Heavy. The bond content of the heaps should vary, the heavier work requiring the highest bond content in the sand. Do not infer that four kinds of sands are required. One standard sand is necessary, suited *in grain size* to provide the desired *finish* for the castings. A *strong bond control sand* having as near the texture and grain size of the standard sand as possible is needed. This is used in varying quantities to replace the bond

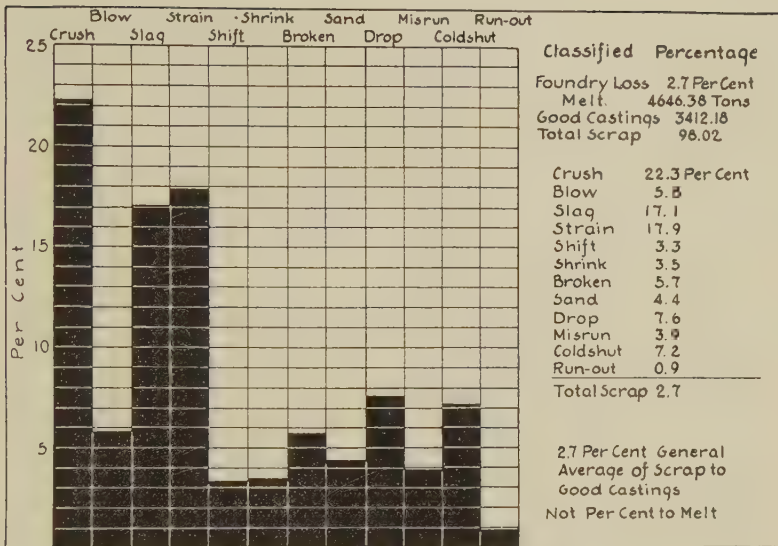


FIG. 1—ANALYSIS OF SCRAP CAUSES.

which is burned out or lost in the casting process each day; also to overcome the weakening effect of core sand, seacoals and other materials entering the heaps. These at all times should receive close attention and be kept at a minimum.

If a number of heaps are used for the same class of work a sample may be taken from each heap and thoroughly blended together and a single bond test made, which would normally represent the average. If an excessive loss occurs to castings from any particular heap, a test should be made from it and compared with the average figure and changes necessary determined.

Heavy work requires a heavier grained sand and heavier bond than the lighter castings. Light work usually requires finer grained sand for surface finish and less bond.

All sand should be kept as open as possible to allow the gases to escape from the mold. The more open the sand and the more thoroughly blended, the less trouble from moisture or scrap losses.

Fine sand does not always mean a fine finish. Greater losses are caused by mistreatment of the sand than from the sand itself. It seems strange that so little reference is made by those engaged in sand research to the use of so many materials in the foundry, which, when used in excess, cause a changed condition of the sand and the resulting losses for which the new sand is usually blamed. These materials have been handed down from our forefathers in the foundry. They are talc, coal, flour, meal, resin, pitch,

core compounds, etc., and from the core rooms all organic matters which leave an ash in the molding sand. Excess seacoal in the facings leave an ash. The use of other minerals, fire clays, cement, brick-dust or like fine materials produce a silt-like condition in the sand, weakening it and filling between the grain destroying permeability. Excess core sands also weaken the sand.

Why blame new sand? Some of the materials mentioned may have all had a proper place in their day, but some of them should now be classed as of the old school. Conservation of these materials might prove more profitable than reclamation of unfit sands.

By a little more intensive study of our molding sands, and the real causes of their instability, plus careful selection and good treatment, blending and tempering; losses should be reduced in proportion to the attention given. Closer relations between the consumer and the producer of molding sands, ironing out the many little difficulties which occur, with a better understanding of the requirements of the foundryman in sand treatment, also the hearty cooperation of the research laboratories and the elimination as far as possible of the use of materials which are detrimental, should bring about results mutually profitable.

The principles outlined in this paper are applicable to the foundries of the East, where low bonds prevail as well as to our Middle West, where there is an excess of bonding material. There is no danger of exhaustion of the supply of new sand. Nature is producing good molding sand cheaper, better and faster than could ever be dreamed of by any so-called "synthetic" process.

MR. SMITH'S PAPER WAS THEN DISCUSSED

E. W. SMITH: In regard to the chart of Fig. 1, I want to show that 70 per cent of this scrap is due to weak sand. You will wonder where the connection is. I place scrap under four major headings: sand, iron, equipment and handling, and there are twelve detailed items of scrap.

The crush loss is mainly due to weak sand, unless your equipment is out of order, which often happens, but which I know is not the case here. Neither is it due in this case to cores; I can vouch for it that the core loss is not one-half of one per cent. Therefore, we put this 22.3 per cent loss under sand.

We have strain loss, 17.9 per cent. Put it under the same column—I naturally attribute it to weak sand. I believe everyone here who is a foundryman would say it is the most logical. If your sand is weak, how are you going to make up your strength in the mold? You will add water. That would be the natural thing to do. As a matter of fact, in the month previous to that of the data of Fig. 1, the strain was two per cent lower, or in other words, it was increased in this month when the sand was weaker.

Excess water increased the blow column. That is 5.8 per cent. Put it under sand defect column also.

Now, with an increase of water, we will just assume that the slag was caused in the mold; boiling metal will oxidize and naturally creates a slaggy condition. Put that 17.1 per cent under sand also. Add them together.

There was some sand in the molds. It is marked 4.4. Add 7.6 per cent for drop outs which is due to weak sand.

Now, I have shown you approximately 75 per cent was due to weak sand. You will possibly agree with some of the conclusions made.

We will now try to determine the loss due to iron. First, we will take out broken. You can't blame that on the sand. You can't blame it on the iron. Broken work is 5.7 per cent and comes under handling.

The next item is equipment. We will take shifted work which is 3.3 per cent. The misrun proves the iron is not very bad. It is the same amount as the shift. You are considering a large amount of metal and 2.7 per cent loss per month.

We now have three of the items. You will blame on iron the misrun, 3.9 per cent, and the shrink, 3.5 per cent, and the coldshut, 7.2 per cent.

Now, for those who don't like the slag under sand where it belongs, I am going to add that to the iron, also. We will blame the metallurgist for that. Put down 17.1 per cent. These figures total 31.7 per cent due to metal.

What else are you going to put on metal? I took the slag away from the sand. How much do you have left to account for it? Take the 31.7 away from the total, 75. It leaves 43.3 per cent.

What are you going to do with that 43.3 per cent? We can't blame it on iron. We can't blame it on sand. Now, what is the foundryman going to do about it? You can't blame slag or any of those items on equipment very well, so we have to say that we have at least, what I have always claimed, very nearly 50 per cent of foundry scrap.

The remarkable thing is our low loss, 2.7 per cent. I have worked five years bringing it gradually down to there, and I can show you month by month where I have brought it down to that point, and I turn around and tell you I have something to work on yet. A man that has fifty per cent or fifteen or twenty per cent thinks he has a hard job. The hard job, is to reduce this 2.7 per cent loss by a half point, and I am trying to work for it. We have to have the help of the technical men in solving some of the problems in the foundry.

MEMBER: Will a copy of the chart be published in the bound volume?

E. W. SMITH: I have no objection. I want you to consider that this is just a personal analysis of scrap, which is what we have all got to come to in our foundries. It is the record of a chosen month.

CHAIRMAN BULL: The record shows a high degree of efficiency. I thing that percentage of scrap is extremely low, and Mr. Smith is quite right when he says that it is harder to cut that 2.7 per cent in two than it was years ago to cut 12 per cent in two.

E. W. SMITH: I want to say, gentlemen, that I have just as much trouble and complaint today in regard to the scrap pile and just as many kicks and comments as I had when I had 10 per cent. Everybody is making progress and the more the foundryman makes, the more is expected.

R. F. HARRINGTON: Will Mr. Smith explain his opinion of the difference between strain and swell. I am not sure how you differentiate between swell and strain.

E. W. SMITH: A strained casting would be one in the form of a fin, showing cracks, and a swelled casting would be where the mold had been rammed soft or the sand would be too weak.

R. F. HARRINGTON: With your explanation, just how do you attribute the strain to a weak sand?

E. W. SMITH: It is just a strained condition.

R. F. HARRINGTON: Is that due to flask equipment or something else? I am thinking about the fin.

E. W. SMITH: The sand covers that. We attributed it to the sand more than we did to the equipment. I have very good equipment. The only cause for scrap that I can attribute to equipment is shift. We are talking of a matter of from seven to fifteen thousand different patterns. It is hard for me to explain the strain. When I mention strain, I mean the finning of a casting. If there was anything I ever hated it was the scrap pile, and the quicker I get it out of the way the better it suits me. If you want to test your sands, begin your testing at the scrap pile. Analyze your scrap pile, then go back to the foundry and find the cause, and you won't be saying much to your molder.

I want to say something I consider is to my credit, and I know it is beneficial to my men. We have not had one molder sent to the scrap pile in five years. Can you all say that? My foremen voluntarily go to the scrap pile themselves.

Materials Handling Session

Two papers were presented before the session on Materials Handling. One, by R. J. Heisserman, was on "Mold Handling" and will be found beginning on page 353. The second paper was by A. Walton on "Materials Handling in Gray Iron Foundries" and will be found beginning on page 235.

DISCUSSION—MOLD HANDLING

CHAIRMAN D. M. AVEY: This subject of materials handling was probably introduced when Cheops built his pyramid and has been interesting most of us from that time forward, and in the foundry industry the matter of getting materials from here to there or there to here was discovered probably a decade ago in its relation to costs.

In America we have the reputation for excelling the foundrymen from other portions of the world in this one thing, the economical, efficient and rapid handling of materials. We owe a debt to the manufacturers of equipment and they, in turn, to their engineers and to the foundrymen whose practical ideas have been of immeasurable assistance.

Mr. Heisserman's paper was a splendid presentation of the economics of materials handling, touching upon the reasons for the manner in which our manufacturers provide certain types of handling equipment. Now, in materials handling in the foundry, I think we all have learned much from the automobile foundry. In these days, when it is popular for those more or less informed to deprecate castings in general, it probably would be well for us to stop and consider how many automobiles it would be possible to produce in this country today were it not for the excellent castings made by the high speed production methods.

J. E. LINABURY: Mr. Heisserman's paper is very complete and covers the subject, but much more can be said on each point.

I have found in some conveyor installations that the full value has not been obtained because only part of the problem, and not the complete routing, has been thought out. In one case, one mold conveyor was arranged to take the molds from so many molders that its speed was too great for satisfactory pouring. The small castings and empty flasks piled up at the shakeout to such an extent that as much additional labor was required here as was saved by the conveyor. Two conveyors half as long and arranged for the disposal of the castings and flasks would have been a satisfactory labor saver.

All of the large General Motors foundries have been completely equipped with conveying equipment for molds, sand, flasks and castings. The return on the investment has been large. In one of the foundries we

are getting four times the production per square foot of floor space. The manufacturing cost here has been greatly reduced. Many of the savings are intangible. The men are held to uniform speed, the sand is tempered uniformly, and the cooling time before shaking out is the same for each casting. These items increase production and reduce losses.

E. F. SCOTT: This is a very good paper and goes into the general trend of development and it certainly is worth while to all the foundrymen here. I think the main development that must be made is to apply material handling equipment to the small user, to the small foundry operator. Of course, there have to be some economic adjustments made and he may have to form some mergers to make his production reach the minimum point for installation of this kind.

Regarding the remark about new buildings, I do not believe that in every case you can put an installation in an old building. I would just qualify that statement a little by saying that we need some new buildings once in a while.

R. M. SCOTT: On page 355 Mr. Heisserman speaks about the sliding conveyors used most extensively for snap flask molds and to handle molds up to 300 pounds. We have sliding conveyors and make molds that weigh 3,600 pounds. That weight takes in the flask, sand, cores, and casting. We built a new building to accommodate the conveyors for our aluminum foundry and I think it is best to do that, although the iron foundry fitted in very nicely with a full conveyor system in the old building. It is all the sliding type conveyors. I just want to bring out the idea that we can slide heavier molds than 300 pounds. We have been doing it successfully up to 3,600 pounds.

We had 108 men making 36 tons of aluminum castings, mostly crank cases and oil pans. Since installing our conveyors, we have reduced the number of men to 67. In addition, we reduced our defects about 50 per cent and, of course, got much better working conditions.

A. C. JONES: As one who is interested in a semi-continuous type of operation, which this paper covered, referring to gravity conveyors for molds, I'd like to get an expression of opinion from some one that perhaps has used these as to what experience they have had on the effect of spilled metal on the economical operation of the rollers; also for snap work, what spacing and diameter of the rollers was necessary, and whether such conveyors caused any shifts or defects in the molds, which would produce defective castings later?

J. J. HARTLEY: I happen to know that there are quite a number of semi-continuous foundries using roller conveyors very successfully. It is quite a particular job selecting the spacing, and in some cases arranging for protection against metal at the end. In one case I know they guarded the end bearing of the roll; in another case the molds are set on boards which overlap the entire conveyor and move forward, the board protecting the roller conveyor.

J. H. HOUGH: We know that we do have trouble trying to handle snap flasks. Probably the best success has been secured through using a

long bottom board on which possibly three or four molds can be placed, and distributing vibration. In that way you can have your board large enough to protect the end of the rollers against runouts and spillage. The diameter of roller and spacing of rollers all depends on the weight. You must first get enough rollers under the load to carry it, and second, to cut down the vibration. Careful analysis should be made in every case.

We have some installations where single molds are handled individually on their own bottom boards. In such cases the batons on the bottom boards must be slightly longer than the dimension of the mold in the line of travel so that the batons advance the line of molds rather than permit the molds proper to touch. Also it is important that the line of roller conveyors has just the proper grade so molds will not move by gravity. Then as the molder places a new mold on the end of line adjacent to his machine he can carefully push it against the batons of the preceding mold and with very little effort advance the whole line. With reasonable care there will be no shifting of molds.

M. W. BAKER: I would like to ask if the success of the mold conveyor is due to the use of tight flasks rather than snap flasks?

J. J. HARTLEY: I can't say that it is due to tight flasks. There seems to be more work going to snap work, due to the handling on roller conveyors. It is done so much more automatically and at lower cost. There is no difficulty whatever in handling snap work on mold conveyors or on roller conveyors. It is being done very extensively.

H. L. MCKINNON: The paper that Mr. Heisserman has presented is a historical narrative which covers the mold conveying industry from its inception up to the present time with a fair degree of accuracy. I want to take exception to one statement, however, and that has to do with that so-called boat type conveyor.

I think I know a little of the history of that, not that I had anything to do with it at the time, because that was before my time in this field, but I did talk with the superintendent of the plant who actually used it, and he stated that the reason it was impracticable is one that any engineer who will look at the proposition ought to see before he ever started to do it.

The method was impracticable because there was no fixed bath for the boats. The boats were just coupled together with a cable, and they were traveling around in a somewhat elliptical path, but just as soon as you start to pull on one point on that you draw the others in, and the first thing you get is friction against the whole inside of the canal. That is what actually happened, and the makers of the equipment built four separate drives. They built twin drives, single drives, all kinds of drives, but they overlooked the one fact that every time they pulled the rope they were just clamping the boats on the inside of the canal. They never did succeed in making it move except by pushing the boats around there individually, because of that one engineering fact, although I think probably the runouts would be a rather serious matter, running in to the water as well.

I also noticed the criticism of the paper on the size of molds that can be used on the sliding basis. Personally, I believe that the day of the

sliding conveyor is going into the limbo of the forgotten past before very long. The whole tendency is toward reduction of power and wear but the sliding conveyor can be made to handle any load. You could put 20,000 pounds and slide it if you put power enough there to do it, and enough surface to distribute the load without cutting the steel. I don't care what the load is, it can be done.

But the question of the economics of it, I think, is open to serious doubt. My personal opinion is that we are coming into the question of minimum of effort and, consequently, minimum wear. In the efforts which we have made in the past three or four years on the perfecting of various types of molding conveyor, the whole tendency has been just twofold, reduction of wear and safety for the equipment and the men.

About four years ago we put in a conveyor in a southern city and although there were all sorts of warnings and guards up, a man insisted on getting between the conveyor and a guard and got his leg caught there, and if it had not been for the very quick action of the operator, who saw the workman's dilemma, the man would have lost his leg, at least.

Now, I find that it is one of the most difficult things that we have run up against to render the equipment absolutely foolproof, to keep men from sticking themselves in places where they will get clamped. I think that is one of the most important features to be considered in mold handling today, that and the protection of the equipment itself, the track and the materials underneath the track from any possible contact with runout metal or sand.

Now, as to the adaptability of this class of equipment to small or large foundries, I believe that it is coming into general use in much smaller units than it was some few years ago. The tendency is forcing some of the smaller operators, especially in the non-ferrous field, to adopt these labor-saving methods.

Mr. Linabury's remark in regard to the removal of the castings is a vital one where the castings are bulky, because that is one of the things for which you have to provide, as well as handle the molds. You have to keep the stream continuous, and the tendency now is to go not only that far, but to cool the castings and clean them without ever allowing them to stop. This thing is being done in a number of industries, both in die cast work and in sand cast work.

The tendency, I think, is to consider the making of a casting a continuous problem from the time the pattern is set down until the casting is clean and ready for shipment, allowing it no place to rest along its path, so that you have the whole problem of material handling from the origin to the finish without any cessation, no place for the hot castings to accumulate and no place except the shipping room for them to lodge.

I. SKLOVSKY: I have one question that confronts the moderate sized foundry and that is the fixing of responsibility for scrap when using a progressive system for making molds. There are several methods that have been used and I would like an expression from some user of mold conveying equipment as to his particular method of fixing responsibility for scrap.

R. M. SCOTT: The scrap is caused by poor iron, careless working, core blows, or something of that sort, and our experience has been just about the same with either conveyors or floor molding. The scrap is not the fault of the conveyors. I know that since we have had conveyors, we have reduced the scrap and defects, and we can trace the responsibility right back the same as if it were made on the floor.

I. SKLOVSKY: When one molder has the total responsibility for producing a good casting, outside of such conditions as poor iron, or improper conditioning of the sand the night before, the loss is directly traced to the molder. When there are three or four men making the mold, two or three others pouring the mold, and a few others shaking them out, do you depend entirely on the inspection of the scrap casting to fix the responsibility for that loss?

R. M. SCOTT: Yes, we do. We can tell whether it is the fault of the drag, the cope, the core setting, or if it is a runout caused by improper pouring or clamping.

I. SKLOVSKY: Do you depend on the group as a whole producing a good casting, penalizing them as a whole?

R. M. SCOTT: Yes, we do penalize the whole group if a casting is scrapped. If the molder has made a crush, the whole group suffers.

I. SKLOVSKY: Does anybody fix the responsibility on the individual making the error, or do they all depend on a group system?

J. E. LINABURY: We take it out of the group. It tends to make each man help the other fellow to do a better job. We have applied public opinion backing us up in getting a good casting, although it is applied differently. With individual piece work, it takes more bookkeeping and probably costs you more when the individual is penalized than when the whole group stands a minimum penalty. We do not then have the troublesome question as to which individual was responsible for the scrap.

I. E. WAECHTER: Is remuneration for pouring handled on the piece work basis the same as the molding or is it handled purely on the basis of day work? The question might be asked relative to the previous question because of penalizing the whole group, unless you have the pouring gang on the piece work basis, the same way as molding and core making, there would be no way of allotting penalty to the pouring group.

R. M. SCOTT: The pouring gang is included in the group. When a casting is lost, every one in that group suffers. The cupola men run in a group by themselves and making the mold, pouring the casting, and shaking out, right down to the janitor are included in one group.

M. J. LEFLER: Is it not advisable in some cases with a continuous mold handling conveyor to have the thing not strictly continuous? We have two types of conveyors, one that is continuous, that is, the whole thing is tied together, and the other one is not continuous. We have cars operating on a track by gravity, going over a hill on each end and coasting down by gravity. In one case, if we have any trouble whatever, as you will have, the whole thing stops. If we have trouble with the shake-out, they can't pour. If we have trouble elsewhere, they can't shake-out. In the other case,

where we have a bank between the pouring and the shaking out and a bank between the shaking out and slingers, and another bank between the closing and pouring, we can have trouble in any station and still continue to operate elsewhere, and then if we have capacity in that station, as we should have to catch up against, we don't lose a thing as far as total molds for the day is concerned.

CHAIRMAN AVEY: Mr. Lefler has presented a question that is one of fundamental design, and I recognize it is likely to be one of difference of opinion, both on the part of engineers and manufacturers of equipment. If there is any comment on that, we would be glad to hear it, of course, reserving judgment as to the recommendations given.

J. J. HARTLEY: I might say that practically all of the continuous systems are designed with some flexibility and surplus capacity, so that if a mold is missed in pouring or there is a delay in metal, the conveyor continues to operate and return the mold later for pouring, the same way on a shake-out. If a mold is not shaken out, the present day systems are largely all automatic and will later return that flask for shake-out, and conveyor speeds are designed to allow a surplus of space on the conveyor so that the molder can continue to make molds for a reasonable length of time without tying up the system.

H. L. MCKINNON: I agree with Mr. Hartley in his statement. We would not think of putting up equipment that was tied down to exactly the capacity. We always allow a margin from twenty to thirty per cent or more, and also some variability in speed, and where they are electrically operated, push buttons are provided for promptly stopping and promptly starting equipment, so that if there is a bank of flasks available, there is no occasion for shutting down operations in a continuous type of conveyor, if it is made with a margin of about 25 per cent over and above the actual requirements. It is started up at full speed and it will clear itself in the first run.

WRITTEN DISCUSSION—SUBMITTED BY D. B. HILL*

Mr. Heisserman has described the pendulum or trolley type of mold conveyor, with all of its advantages as expensive, due to costly overhead supporting steel structure.

A conveyor of the trolley type has been perfected which has all of the advantages described by Mr. Heisserman and is not expensive.

The trolley in this conveyor consists of two large diameter, single flanged, chilled, tread rollers equipped with roller bearings. They are mounted on an axle from which a forged steel trolley stem is suspended. The chain is attached to the stem, approximately midway between the rollers and the pendulum point of support.

The rollers travel on a track of two parallel steel angles or T-rails, the track angles or rails are held to gauge by a malleable iron bracket which in turn is attached to the supporting structure overhead. Due to

*Palmer-Bee Co., Detroit.

the design of this double angle-track, it is possible to maintain longer spans, thereby reducing supports considerably. These supports are made in the form of a cross, or the entire structure may be suspended from roof trusses.

The chain is of short pitch, and for small flasks sprockets may be of a small diameter and carriers spaced close together.

In the field of the tray type conveyor there has been developed an improved design covering this field. The trucks are fitted with six roller bearing equipped wheels. Four of these wheels are single flanged and carry the load. Two are straight faced and serve as thrust rollers. The trucks are coupled together by a telescoping device, giving each unit an individual take-up action. The entire train of trucks operate upon a track of two parallel T-rails in the form of a race track or speedway. The curved portion of the track is fitted with two guide angles, forming a circular groove through which the thrust rollers operate.

The train of trucks is propelled by means of a variable speed caterpillar drive. This unit is very unique, due to the absence of large sprockets and a heavy conveyor chain. The tracks in this case are shielded, as described by Mr. Heisserman. The tray tops have been made of cast iron with a planed surface, with a series of small cored holes through it. This allows them to be used as a bottom board, the cored holes serving as vents.

CHAIRMAN AVEY: I think the entire question in the discussion by Mr. Hill is one that has confronted manufacturers of conveying equipment right from the start. I can recall when one of our men, Mr. Diller, saw one of the early installations of a complete conveying system. Everything was tied up together in that system and the limiting factor, the thing that tripped them up, was the matter of lubrication on their long conveyor. They had a system or series of pull cords with whistles to stop the work. They had not reached the push button point yet. They had a man running along with an oil can all the time. Now, we have traveled a long ways since that time, and I think our engineers and manufacturers of equipment have whipped that very satisfactorily.

DISCUSSION—MATERIALS HANDLING IN THE FOUNDRY

CHAIRMAN AVEY: Mr. Walton has given us a very exhaustive discussion of a very interesting angle to this equipment business, this handling matter. His viewpoint represents that of the engineer, and engineering, after all, represents the application of judgment to known facts. I realize that there may be opinions which may be different, held differently by different men, and I realize also that many of the facts which are set down are fundamental and axiomatic.

I. SKLOVSKY: The standardization of foundry equipment assists in the maintenance problem due to the familiarity with the particular equipment gained by the maintenance crew. From this standpoint, the practice of standardizing foundry equipment is highly desirable.

Consider, however, a foundry with a fairly uniform production for a number of years, during which time equipment is added in small amounts and of the same type as the old equipment. A time comes when a large amount of equipment must be added for an increase in production and this foundry has had experience with the use of only one type or make of equipment upon which to base the selection of new equipment. Either they once more buy equipment similar to what they are using, which by this time is inferior to the newer types, or they buy a large amount of new equipment without having actual experience with the new type.

On the other hand, from time to time they buy small amounts of equipment that is not standard with the bulk of their equipment. They have already gained the experience in the use of that equipment and can better decide upon which type of equipment to buy.

In regard to the use of concrete for floors and gangways in a foundry, Mr. Walton states that a concrete floor cannot be used as molding space. We have a foundry that has been in operation seventeen years which has concrete floors for the molders. In regard to the gangways, concrete covered with iron plates is better than plain concrete gangways.

A. WALTON: I think Mr. Sklovsky's criticism is perfectly just on the standardization of machinery and equipment. He took a little different view than what I mentioned. I did not mean, of course, that any one having once installed a certain type of equipment should not be progressive. I said later on that we fully appreciated that we advanced from day to day and, of course, a time would come in any foundry, whatever its equipment may be, when they would have to change and adopt improved equipment.

But I have been in many foundries where it was not because they were buying more modern equipment that they bought different equipment. The new equipment they were buying was probably not any more productive than the old equipment, and in those cases it was somewhat of a detriment to it, and that is the point I had in mind.

H. O. HAUGHTON: I notice that Mr. Walton refers to some applications of lifting mechanism. In part C he mentions direct cupola charging by magnet. I think that is a rather interesting subject. Just how do you handle it? What do you figure on the magnet's picking up, a definite weight, or do you have to weigh the charges first and then pick them up by magnet?

A. WALTON: Weigh them first and then pick them up from the charging floor to put in a furnace.

H. O. HAUGHTON: Will a magnet handle a mixed charge that way?

A. WALTON: It won't for a very large cupola but it will for a small cupola. I have seen such installations working very satisfactorily.

H. O. HAUGHTON: You say you had to charge your material in layers, your pig, then your steel, and then your heavy scrap and your light scrap. What if the steel were quite bulky, as in the form of flashings?

A. WALTON: You have to prepare your work for it. Those that use that system have to prepare the charge so they can handle it efficiently. It naturally applies only to metal. The magnet would pick the charge up and drop it into the cupola in approximately the same order.

E. T. BENNINGTON: I think I can say a word on that point in supporting Mr. Haughton. There is a disadvantage; if you have a magnet on a hoist or crane to charge a cupola for when you are charging your limestone and coke, of course you can't handle that with the magnet. The result is you have to attach and detach the magnet. I think the installation Mr. Walton has in mind must have used more than one crane, which would mean a duplication of equipment, or more than one hoisting device to complete that charging.

A. WALTON: Yes, they have.

E. T. BENNINGTON: Magnets are very useful. It is quite a little trick to get them on and off the hook.

A. C. JONES: I'd like to have interjected some discussion on bottom boards in connection with gravity or continuous conveyor system and learn whether metallic bottom boards are more of an advantage in this practice than they are in the old method.

H. L. MCKINNON: Runouts, of course, are much more damaging to wooden bottom boards than they are to metal bottom boards. On the other hand, the metal bottom boards are heavy, hard to handle and for certain classes of work, unless they can be made of light metal like aluminum or magnesium alloy, or something of that kind, they require crane handling, which wooden bottom boards do not. On the regular conveyors, I would see no reason in the world why a wooden bottom board can't be used. It is more economical.

J. H. HOUGH: I would say on molds up to one hundred pounds wood is better than steel.

R. R. KENNEDY: We have heard a lot from the representatives of automotive foundries who have large production, but I'd like to hear from any one who operates a light foundry and has had any experience in automatic conveyor equipment. We have a small foundry making a large number of castings, about 20 or 24 tons a day, but the work is of rather a diverse character and rather light. I'd like to know if anyone present has ever had any experience along those lines.

A. WALTON: A few months ago I was in the foundry of William Laytham and Sons in Passaic, New Jersey. They are a jobbing foundry making small castings, the largest not running over a few hundred pounds in weight. They had two units installed within a few months, and they have greatly increased their production. They had twelve machine molders working on each side of the units, making twenty-four molders. The plan worked very well, indeed, and was the first installation I had seen or known of in a foundry making small jobbing castings. I have no doubt at all if you get in touch with those people, they will be glad to tell you more in detail than what I am able to tell you of them.

E. T. BENNINGTON: There is one thing Mr. Walton brought out that I think could be enlarged upon. That is the subject of standardization. There are arguments in favor and against standardization. I would like

to add something from the standpoint of the material handling machinery manufacturers.

Quite often we get into plants where the foundrymen or engineers want to decide on the size of bearings, the size of wheels, and things of that sort, and I think those are matters which should be left up to the manufacturer who will assume responsibility for his judgment. The overhead conveying equipment manufacturers and I believe most of the manufacturers of material handling machinery are standardizing their own product. That standardization can mean a whole lot to the foundryman because it enables the reductions in manufacturing cost to be effected, which in turn, in the long run, go right back to the foundryman. Then the process of evolution, of refining, developing details, and things of that sort, can be much more easily handled and development can go much more rapidly if the manufacturers are permitted to use their judgment on a great many of those things. From that standpoint standardization is a big thing. It is something which carries a great deal of weight from the manufacturer's standpoint, and it is important to the foundrymen, too. It saves them on repair parts. They have one set of repair parts instead of a different set all the time, and I think it is something that ought to be enlarged upon.

J. E. LINABURY: There is one other means of conveying that has not been mentioned here today that I believe is of interest to foundrymen. At some of the General Motors foundries located near water, refuse sand is deposited in a concrete pit and water is pumped into this pit from a nearby river. By means of a sand sucker, the mixture of sand and water is then pumped through a five inch pipe to low land nearby.

Where people have a large amount of refuse to dispose of and are using trucks or push carts or other methods, it takes a number of men or horses or trucks, and this suction method is such that one man can operate it if he has the water and the low land nearby.

That same method is used to take away the dust from dust arresters, which is discharged right into the pipe and running water and carried out to low land, and it makes absolutely no dust. As you all know, when you empty your dust collectors, they are uncomfortable places to be around.

CHAIRMAN AVEY: This question of fluid transfer of materials, of course, has had consideration in connection with the water type sand blast, but I believe there they have to resort to a grab bucket to get it away. I think Mr. Linabury has added a thought in that line.

D. W. MERRIMAN: I would like to get some information from some of the gentlemen on core plates, and the handling of cores, whether there has been very much success with the asbestos press plate a half inch to five-eighths thick. I have only been in the foundry business a short while, and a year ago I tried out some asbestos plates on account of weight, they being lighter for the men to handle. We got very good results, keeping light cores very straight, and for the past year we have been using plates of this type, and they have kept straight, but I don't know how long the life of them might be.

These plates are flat without any ribbing at all. They were straight when I got them. I specified a very straight plate. Some of our cores will run out eight inches long and a half inch thick, that is, for an inch core, one neck of the core and the other part of the core will be eight and nine inches in diameter, making them in two pieces. We have to keep the upper end very straight and flat.

R. M. SCOTT: My idea would be that the cores might not cool evenly. We use aluminum plates and get a uniform core. They are ventilated below.

MR. KINNEY: I have a little foundry, operating with about 35 molders, and we pour between 15 and 20 tons a day. We have outgrown our capacity, so we bought about five acres of new land to start with, and we have all the room we need. We are going to put up a new foundry and are now ready to build.

I am interested in sand handling and all the modern conveniences and equipment that you have in the east. I have about half of my molders on the floor. I run about five squeezers. The rest are on the benches.

I'd like to get started right. What should I put in first in the way of machinery to eliminate labor? I am cutting my sand at night now with three Mexicans at \$5.00 apiece, and I don't have any sand trouble.

A. WALTON: I really think that if you are going to build a new foundry, there is no excuse for not building a modern one. The principal purpose in my writing this paper was to give encouragement to the less modern foundries to rehabilitate their outfits and get onto a level where they could manufacture castings cheaper and stop talking about the other fellow that is making them at a less price than they are making them at.

The first thing you want to do is to make sure that you are going to have your raw material stock alongside your cupola on the outside of your foundry, so that you cut out having to carry the varying distances, all of which costs money, and if you can store your pig iron and scrap and coke and limestone adjacent to the cupola side of your foundry, and if you are pouring 25 to 30 tons a day, I think you ought to have a small charging machine. It ought to help you considerably.

Then, of course, the next step would be your sand preparing and conditioning machinery in order to save buying new sand too frequently. The development in connection with the improving of sands, etc., is getting to a point where I think in the built-up sections of the country before long, where we have many foundries, there is going to be less and less natural bonded foundry sand purchased.

A few months ago I was down in South Jersey and saw an operation there which was being built by one of the biggest foundry sand producers in the east. He had nearly three hundred acres of fine silica sand, perfectly rounded grains of varying sizes, of course. He spent money on a big screening outfit, so that he can screen that sand, getting out of it four or five or six different grain size standards, which will give him steel foundry sand and other grades all the way down to sand required that would have the possibilities that are in Albany sand.

Alongside of that screening outfit he is building a bonding outfit, whereby he will take these sands of different grain size and will blend sands to the specifications required by different foundries, giving them the same grain size and same percentage of bond on repeated shipments.

A great deal of that kind of work has been done by our large foundries on their own behalf, and they have been very successful, and I think the big molding sand operators are also going to get into that game, a good many of them, within the next few years.

Then, if the nature of your jobbing work is such that you can use the conveyor method of molding, like I described was being done in this jobbing foundry in Passaic, you then again would be way ahead of your other competitors in your district who probably have not had anything of that kind to date.

MR. PROBST: It has occurred to me that perhaps the scale feature in materials handling may have been overlooked. May I offer as a suggestion that there be interjected into the material handling picture, the consideration of placement of scales, as we consider scales of extreme importance in these days of speed and accuracy and the close specifications with which you foundrymen have to do your stuff these days.

WRITTEN DISCUSSION—SUBMITTED BY D. B. HILL*

Mr. Walton lists 17 operations carried on in the handling of materials in the modern gray iron foundries.

We would like to add a few operations not included but which are gaining in popularity.

He lists Item No. 11 as delivery of castings to cleaning room and to tumbling barrels, sand blast machinery, etc.

This operation has been broadened to include the cooling of the casting during its course of travel from the shakeout to its resting place in the tumbling mills.

As carried out in several of the modern auto foundries, this operation consists of the castings being picked up at the shakeout either singly or in perforated buckets or containers by an overhead trolley conveyor. This conveyor is designed so that it leaves the foundry building proper and travels underneath a cooling shed with outsides permitting the castings to be exposed to the air as much as possible. This travel can be as long as required to cool the casting to the desired temperature for handling.

Castings with a large quantity of coarse sand are conveyed to the knockout building where the coarse sand is removed and recovered together with wires, gaggers, etc.

The castings are then sent to the cleaning room where they are unloaded on a section of gravity conveyor located in front of the tumbling mill. The gravity conveyor accommodates a load of castings until the present mill load is emptied.

*Palmer-Bee Co., Detroit.

Core Oven Conveyors

We would like to add as operation No. 18—Handling of cores through core ovens.

The use of continuous core ovens in recent years has cut core room cost considerably and has increased production in the same floor space.

The two most popular types of core ovens are the vertical and horizontal; the horizontal type can be fitted with a single chain of the trolley type from which the core racks are suspended by a single suspension point or two strands of chains with the trays or racks suspended from cross rods attached to the chains. The vertical type is equipped with two chains as described above.

The use of continuous type ovens has resulted in the elimination of expensive lift trucks, core racks and a reduction in breakage of cores from rough handling. To these advantages we may add that cores are better baked due to proper baking time and continuous movement of the cores. They are received at the discharge end of the ovens at a proper temperature for handling.

The conveyors covering this type of work may be extended past the confines of the oven serving the core makers in a manner that reduces unnecessary motions for loading the cores. A feature especially unique in this regard is the sloping of the conveyors as they pass along the line of core makers permitting the top and bottom shelves of the racks to be loaded with equal ease.

Foreman Training Session

The session on Foreman Training was a symposium. The subject was reviewed from several angles and the papers presented were by W. F. Coleman (beginning on page 539). A. R. Peirce (beginning on page 451), M. H. Mellen (beginning on page 533), G. A. McGarvey (beginning on page 343), and A. D. Lynch (beginning on page 385).

DISCUSSION—FOREMAN TRAINING

L. A. HARTLEY: I have visited different plants and have seen various types of foreman training and instruction and conferences in progress; and as a representative of one of the major associations in industry, I want to extend to all of those agencies our hearty approval. They all have done wonderful work, individually and collectively. The work of the federal board for vocational education is also quite well known to me, for I was early in that work as a state supervisor of industrial education.

Whether it be foreman training, foremanship training, or training for foremanship, they all mean the same thing. None of those phases of vocational education is on trial. We have had training in the industries ever since we had industries. We have had training for foremen ever since we had a foreman and we will continue to have foreman training as long as we have foremen. The only questions remaining are—what kind and how good?

The introduction of molding machinery made a big change in the foundry industry. It not only changed the operations in the foundry, but it changed the operations of thought. The psychology of the management of foundries was wholly revolutionized by the introduction of the molding machine.

There came a struggle in the foundry industry. It is so well known that I need not comment on it.

The world is not the same as it was twenty-five years ago. It is a different world we are living in, and new times require new methods and new men. In 1917, for instance, America ranked with Russia and China in vocational education, and today it ranks among the leaders of the world. That shows how rapidly we change in America. Today the great need in industry is friendship between the men in the plant and the management.

A factory cannot wave hello; a factory cannot smile. It is a thing that has been understood to be made of brick and stone and steel. Our job is to make it possible for every man who works in every plant to feel that that factory is his friend. Friendship makes all the difference between drudgery and happy work. It sends a man home happily to his

family whether he is a manager or a laborer. No job should be done without a human interest behind it. It is criminal to have men work without an interest in their job. Faith in the work we do as a means to human happiness and success in our own lives is absolutely essential to a harmonious government. We have to make money in order to make men, but to make men while making money is a worthy objective that we all should share.

H. DIEMER: Mr. Coleman stated that he does not think that the conference plan alone covers the needs of foreman training. I would like to have him explain that a little more and tell us by what other agencies or methods he would supplement the conference and the discussion plan?

W. A. COLEMAN: The thought I had was that foreman training, for the most part, should be done on the job itself, that more of it should be done while the foreman was working at foremanship, rather than in a conference room. If you want to teach a man to run a lathe or a mill you go right to him at the lathe or mill and teach him there. Now you can do the same thing with the foreman at his post in his individual problem, and I think you will get more results right there than you will in the conference.

H. DIEMER: In other words, you carry the conference idea to this extent, you want to see that the foreman puts into practice the ideas that the conference has stimulated?

W. A. COLEMAN: Yes, that is why I suggested in my paper that if the place is big enough, a competent teacher be put in the plant, going from foreman to foreman to teach the man foremanship at his work where it will sink in most.

S. M. BRAH: I would like to ask the gentlemen who have had experience in foreman training whether there is any place in the training of foremen, for training along shop practice and technical lines? Most training follows along the lines of industrial management. Very little seems to be said at these foreman training meetings relative to the training of the foreman as a better mechanic, or as a better technical supervisor. Is there any place in foremanship training for training of this kind?

T. D. LYNCH: I think the suggestion Mr. Coleman just made is a solution to that problem. You cannot bring a group of foremen representing foundry, machine shop, assembly departments and various other departments together and spend time educating a man on certain mechanical questions that apply to one of those departments while the others sit and listen in. That is a problem for your manufacturing superintendent with the individual foreman in his own line. There is another thing that makes the fact that you cited true; namely, that those things do not appear in foreman training. It is raised by the question, where do most of our foremen come from in industry today, in your shop and ours and all the shops? In 95 per cent of the cases they were selected for the job because of proficiency in the operations they were doing in the specific departments where they were placed. Theoretically, at least, a man is better fitted for the mechanical end of his job than any other end when

he takes a foremanship, and it is in the other things that he is most deficient and most needs the training; but if he is not fully competent along mechanical lines, that is going to be a case for individual instruction from a superior in the organization.

S. M. BRAH: To a certain degree, that answers my question. I do not know whether this is universal or not, but I have had the unfortunate experience of witnessing a great number of foremen being chosen not for their mechanical ability as much as the fact that they are good fellows and very often these so-called foremen were nothing more than overseers who for technical skill leaned on the superintendent of production. All too often that happens, and in our particular case in the Tri-Cities, we have some very sad cases of that at the present time. Here is a group of foremen in a production shop. Those foremen were picked because they were good fellows and they are leaning for help on the manufacturing superintendent all too often; and while we recognize the need for training along industrial management lines, we have sorely felt the need of training along this other line and we are a little perplexed as to just how to tackle this particular problem.

MR. HABER: The Tyburn Oil Company has a very effective two-year school of training in the processes and products of the oil industry entirely distinct from their foremanship training, and I think that plan might well be adopted in many other industries. It is a carefully prepared course in the technique of the industry. I do not believe that foremanship or management teaching should be complicated by including in that particular training processes and products training, which may well be made the subject of separate training courses.

T. D. LYNCH: It may be that Mr. Brah's industry needs more apprenticeship training, needs to develop more men in the art and practice of the business he is in. If men are not available who are trained in the mechanical processes of your business, that is certainly what you need. If there are men trained in the process and capable of doing it, and you are selecting foremen because they are good fellows, you are entitled to all the trouble you get.

S. M. BRAH: Our apprentice training activities are only three years old and we will not be able to harvest the fruits of these activities for a few more years. We are concerned with the foremen problem today, and while we are building for the future, we are trying to help ourselves on this particular problem immediately.

H. W. STICKLE: We do not keep foremen if they do not make good. We do have these conferences. We have a very varied line of manufacturing; one department is as different from another as black from white, so we have to have foremen of special training and special ability, and if they do not fulfill their duties as foremen we have to get rid of them. I think we have had five foundry superintendents in the past year. We even came to Chicago to get a foundry superintendent. He lasted one month. While each one of them had some special qualifications that were good, they were lacking in a great many others, and as a last resort

we selected a man who had been trained in our own foundry, a molder and a man who was in charge of our store-house at the time, and in two months he has made the best record of anybody we have had there. We do not know how long that will last.

S. M. BRAH: Mr. Stickle certainly corroborated the point I tried to bring out and his plant is no exception, and our community is no exception. Not so long ago I happened to be sitting in a hotel and I saw half a dozen men with whom I was acquainted, every one from communities within two hundred miles of the Tri-Cities, and what were they trying to do? They were trying to hire our high grade foremen down in the Tri-Cities for jobs in Peoria, Springfield, Rockford, Aurora, and even Chicago. Now I firmly believe that most of the communities are not aware of their problem. A few minutes ago some one suggested that maybe we expect too much from our foremen. This is not the thing; I understand that not enough of us are training foremen; we realize that we must train foremen and we realize that we must train them along industry management lines. We also realize that we must train them along this other line and are a little uncertain at this time as to how to go about it.

I am here to try and learn from you gentlemen, the people in this great industrial community of Chicago, as to the various methods. We cannot go into a trade school proposition such as they have here in Chicago or Milwaukee or Detroit or Cleveland, because the public schools systems of the Tri-Cities object to spending \$1,800 for an apprentice instructor for one year. We certainly cannot expect them to spend very much for vocational training, so we are looking for some means whereby the industries themselves can do it. We have two or three methods under consideration, and I am here to ask assistance, to learn from you gentlemen, and the people in this community, how we can lick this problem that I believe is ours. There are many other communities in the same position as the Tri-Cities. I don't make any apologies for the Tri-Cities; in fact, some people think we are better off than other communities because they come down there and try to hire our foremen, but the fact is, we are all deficient in this particular matter, and I think we will do well to get together.

H. J. ROESCH: Have you ever thought of organizing a superintendent-foreman's club in Tri-Cities? We have one in Chicago with a membership of 400 men and the subjects of the meetings are usually technical subjects dealing with the machine set-up; for instance, the Brown and Sharpe people send a man in to tell how to tool up an automatic screw machine, etc. Have you ever done that?

S. H. BRAH: We have five technical societies, the Steel Treathers, the American Society of Mechanical Engineers, Quad City Foundrymen's Association, etc., but we cannot seem to cover enough ground. It seems to be a little too slow. I would be glad to learn more from you on that line, Mr. Roesch. Our meetings seem to be just a little too technical for the average foreman. A man will come along and talk about composition of iron and steel, martensite, austenite, etc., and finally some elderly

gentleman will get up in back of the hall, and yell out, "Who makes this steel?" thinking it is a trade name, so it is my thought that we probably have been too technical in some of our meetings and I would like to have the name of those people who will give us some information. We have five technical societies. We have a foreman's club. Deere & Co., with six concerns, have about 400 foremen alone. They meet but their function is primarily social.

A MEMBER: Suppose you have a weekly meeting on other problems which takes up half a day and which is a part of the organization and has been going for years, and is special to the operation of the plant; will it be feasible to have foremanship on the company plan and in addition to that, if it were not, has anybody had any success at all with foremanship for volunteers on their own time?

M. H. MELLEN: We have not at any time held our foremen's conferences on employe time. They have always met on company time. We hold other meetings in the plant on company time which we call "departmental meetings." A plan of employe representation has been adopted at the Lynn Works and representatives from this plant meet with the department heads and their assistants to discuss various shop problems, but these meetings are not associated or connected in any way with foreman training. Is that what you had in mind?

A MEMBER: It does not quite answer the question, because the thing that worries me is the limit to which you can extend the time the man is absent from his department; in other words, if you set up too many meetings in the company's time, you soon get to a place where a foreman hardly sees his organization.

M. H. MELLEN: Yes, I think there is danger in that direction. Our foreman training meetings are held once a week, while the departmental meetings only happen once a month.

S. M. BRAH: What particular method of foreman training seems to have the most numbers, the conference method or the lecture method, or a combination of lecture and conference? Can anyone tell me that?

L. A. HARTLEY: Most of the training is in conference. I am not saying, however, that I think that that is the most effective. I think the most effective method is that which works best in a given situation, and I think that if we do not recognize that fact we are overlooking a big bet. The whole situation revolves around the thing I mentioned, a lack of interesting the right people in the right things, and that is a problem of management.

G. A. MCGARVEY: In answer to the question asked by a previous speaker about the number of foremen in training, I would suggest that you write to the U. S. Chamber of Commerce, and ask for their bulletin on foremanship. This is the only country-wide survey that I know of which gives a tabulated list of foreman training meetings that have been held of all types and the number attending. There is another point in regard to the pretraining of foremen which may be helpful to those in charge of the Tri-Cities program. The Westinghouse, East Pittsburgh

Branch, has a pretraining plan for foreman assistants. Also a number of industries in the smaller cities of New England upgrade the men for supervisory positions. Following the apprentice training course, other courses are offered to prepare a selected few to act as assistants to the foremen. This is universal in some centers; the foremen all come up through the ranks. Personally, I think such a plan is ideal.

E. H. BALLARD: A large percentage of the ranking foremen in our plants today are graduate apprentices. The general superintendent of the River Works, recently appointed, is a graduate apprentice. The general superintendent of the West Lynn plant is a graduate apprentice. Those apprentices who have graduated from the specific course to fit themselves for something better have been stimulated and have a personal interest in the further study of a subject that they are not proficient in, and until foremen or any other men want to seek elevation and take a little personal interest in teaching themselves those things in which they are deficient, you will never have an executive force that is worth much.

M. H. MELLEN: I did not want to introduce the subject of apprentice training into this meeting, but since Mr. Ballard has opened it, I do want to say that you will have no trouble with your foremen if you properly train them in the first place. At the Lynn works we have maintained an apprenticeship system since 1902 and we now have over 1,200 graduates. From these graduates the management is now picking their supervisors for the plant. The general superintendent of the West Lynn works where 3,000 people are employed is a graduate apprentice, and you may go down through the whole organization and you will find a large number of supervisory positions filled by graduate apprentices, both at the river works and the West Lynn works. Mr. Ballard has just taken six into his department, and not a one has turned out to be a dud. I pointed out in my paper that the reason why we have introduced foreman training into our apprentice curriculum is to anticipate the problems that arise and prepare these young men so that perhaps they may not make the mistakes they would if they had not been given this training.

C. J. FREUND: You say in your paper that foreman training becomes a part of the apprentice course during the last three months? Is that compulsory for all apprentices or to only a select few?

M. H. MELLEN: Generally it is compulsory and includes most of the apprentice graduates as the training is not scheduled until the last three months of the course, and the apprentices have then been carefully selected. When we hire an apprentice we put him through a course of sprouts and eliminate all the undesirables, and a young man is never sure of graduating from the course until he has completed all his time. When we bring him up to the end of his course, we feel quite sure that he is the material we want; and so, with a very few exceptions, practically all the apprentices who graduate receive this specialized training in foremanship. We graduate from 90 to 100 apprentices each year. Last year we graduated 90 and they are being absorbed into the organization of the company just as fast as

we graduate them. At the present time we have 325 apprentices in training.

E. B. SWEENEY: My idea is to get the management side from the point of view of foreman training and find out how to sell a hard-boiled manager the idea of a training course.

E. H. BALLARD: There is naturally a little difference on the part of many men to going into a course of that kind because they do not know much about it. The average foreman, after he has had contact and sees what the managements are really trying to do and that they are trying to put something in his hand to educate him to better his position, is a mighty poor foreman indeed if he will not take full advantage of it, and cooperate to the fullest extent. In our foundry group, our men were thrown in with pattern makers and foundrymen and a few machinists, and, naturally, some of the subjects were not closely allied, but it was a mighty fine contact, because some of our founders found that the machine shop men were quite good fellows after all. It was just a matter of getting these fellows together.

M. H. MELLE: Of course, this question of foreman training was first sold to our manager, and he started me in on the job. I made a survey of the plant, and submitted a plan which he approved. This I was told to put in operation. I remember I went to one of our division superintendents and said, "We are going to start foreman training in the plant on Monday. Will you be ready?" He looked at me with a grin and said, "Are they going to start those things again in the plant?" I said, "Yes." He proceeded to argue with me and I said, "I don't want to argue this matter with you. I have been told to start the work. Will you be ready to start on Monday?" He said, "Why pick on this building." I said, "We have to start somewhere and I have been told to start with your department." He said, "All right, we will be there." His organization became interested almost at once and after a few weeks he was so thoroughly sold that he said to me and to our industrial relations manager, "These conferences are fine. I am noticing a difference in my organization already. I find more cooperation and the men understand their problems better. I have just told them that I want them to attend all meetings and get all they can out of the conferences." From that time on, we had no difficulty. The thing sold itself.

J. CARMODY: I spent twenty-five years in industry, starting at the lower ranks and coming up through various stages, superintendent, production manager, vice-president, etc. I found that the men who got furthest and the men who were easiest to train were men who read their industry paper. The man who is ambitious is the man who reads about what is going on in his industry elsewhere. Things are changing so fast that no one single man today can keep up when off by himself, nor can he keep his group up to the developments in the industry. Things that the pure research men are finding out now will be applied in industry within six months instead of ten years, as happened twenty-five or thirty years ago. I do not know of anything that can be recommended to men

that will help them more than to read the papers in their industry. I say that because I know hundreds of editors, I know the money they spend to search out new ideas and put them before their readers as rapidly as they can. This problem Mr. Brah mentioned of a man getting up in a foremen's meeting and not knowing anything about the new material used in his industry could not happen if the man was conscientiously reading his industry journal. I know of cases where men who sell these journals cannot get into the plants; the general manager won't allow them in; the superintendent does not want them to see the foreman.

Another point, when I was in industry, I invited in the best men that the equipment manufacturers had who were serving our industry and had them tell our foremen how best to operate the machines. No foreman's training course can be successful unless the man who leads is a real leader and wins the confidence of the men in the class, partly because he understands their problem and partly because he is a wholesome man in whom they have confidence.

A. R. PEIRCE: Answering the gentleman who mentioned the so-called hard-boiled manager that could not be sold on the need for a foremanship program, I have had considerable experience with managers of that type and in most cases they think they are doing a bang-up job of training foremen because they call their foremen together for a production conference once a day or once a week. These managers honestly think they are training foremen because their foremen get together in these meetings.

Right here I want to say that there is a sharp distinction between the two words, foreman training and foremanship training, and it is important to keep that distinction in mind if you wish to adopt a real constructive program. We have styled our program foremanship training, and in that way we make a distinction between the general constructive program and the production meeting.

Another excuse that these so-called hard-boiled managers offer is that their foremen do not need training because they have been foremen fifteen or twenty years or even longer and they know all that there is to be known about being foremen. In plants where this condition exists, we usually can do the best job of foremanship training, because those fellows are still trying to do everything as they did fifteen or twenty years ago and it won't work today. Foremanship training cannot be, in most cases, sold at the executive's desk but if he can be induced to attend a conference in some other plant and sit in as a visitor, he may be readily convinced of the merits of the conference plan.

In our particular work we often induce the manager to let us come into his plant and call his foremen together and if he will furnish us with a blackboard, we will demonstrate how this conference work is done and show him the benefits that may be had by its use as well as prove how little his foremen know about some comparatively simple subject. I mention these experiences to give you an insight into what actually goes on in this field of endeavor.

CHAIRMAN BERGSTROM: Does everyone understand the conference method of foreman training? Will Mr. Peirce and Mr. Roesch go to that board about two minutes and give the members a little idea on the conference method of foreman training?

A. R. PEIRCE: There's a good question to discuss, "What are some things that the management has a right to expect of their foreman?" Now that is something everybody here should have an idea or two about. Will somebody give me one idea?

Members mentioned the following qualities: Loyalty, honesty, ability, job-skill, job-interest, interdepartmental cooperation, taking an interest in their workmen, responsibility, assuming full responsibility for everything in their department, good housekeeping, initiative, interest in details, ability to plan, carrying out company policies, and understanding company policies.

MEMBER: When does the average shop hold their meetings? We hold our meetings in the evening and pay our men extra for the meetings. Our meetings start at 7:30, then the men have time to go home and change their clothes and come back refreshed and we pay them to attend these meetings. We hold it compulsory to attend these meetings.

A. R. PEIRCE: The majority of the plants in the National Metal Trades' Association hold their meetings during working hours, and with very few exceptions those that hold them after working hours furnish a meal and pay for it, and the attendance is voluntary. When the meetings are held on the company's time, attendance may be made compulsory, but, as a rule, it is not feasible to make such a rule when the meetings are held outside of working hours.

MEMBER: Some plants handle it in that way, and it is very unsuccessful. They have an attendance of about 60 per cent where we have 100 per cent.

W. A. COLEMAN: I think it depends entirely on the size and nature of your plant. As I tried to bring out in the paper I read, if you have a jobbing shop or work of that nature, evidently you cannot take your men out during working hours and have a conference, you cannot go an hour without the use of the foreman. That is also true, with the small plant, and the great bulk of the foundries are small plants, and there are not as many foremen in regular foundries as in other sources of industry. You cannot take all the foremen out of a small plant and bring them into a conference during business hours. It has to be done after business hours.

MEMBER: We have a conference every two weeks. I would like to have constructive criticism on that. The way I handle this matter is by appointing a group of foremen to pick out some of the men with the best ability that we have in our plant and recommend them for these meetings; we only have about twenty-two foremen, and our apprenticeship class in foremanship at the present time is ten and they are recommended by that committee. We put them in that class and we are teaching them, leading them up to take foremanship jobs in our organization as they occasionally come up.

General Foundry Practice Session

Four papers were presented before the session on General Foundry Practice. These were "Use of Scrap in Gray Iron, Malleable and Electric Steel Mixtures," by E. K. Smith and F. B. Riggan (beginning on page 51); "Baking Practice for Oil Sand Cores," by H. L. Campbell (beginning on page 289); "Core Oil Testing," by V. A. Crosby (beginning on page 526), and "Safety Considerations for the Foundry," by F. H. Elam (beginning on page 323).

DISCUSSION—USE OF SCRAP IN GRAY IRON, MALLEABLE AND STEEL FOUNDRIES

J. T. MACKENZIE: I question Mr. Smith's results on the effect of 5 per cent tin. Of course, the addition of zinc in the ladle or cupola would probably result in getting very little of it in the solution. Taking the results from Mr. Smith's Table 4 on page 57, an all-scrap mix gives a transverse strength of 3,750 pounds. Then when he puts 5 per cent of tin in it, he only gets 2,350 pounds. Table 5, in which he compares the tin, shows a poor set of mixtures; for instance, all burned material, all borings, and the other one with the zinc scrap. I don't think that is fair; I think he should compare it with the 100 per cent scrap mix on Table 4.

On page 65 Mr. Smith says "Cupola mixtures are flexible as the steel takes up about 2.7 per cent carbon from the coke." I think it should be mentioned that that is a statement that should be qualified as to the blast used and the percentage of coke and the quality of the coke. I have tapped 100 per cent steel from the cupola at 4.45 per cent carbon, and I have tapped 100 per cent steel at 1.35 carbon, depending on the amount and kind of coke used. In the same way, in Table 6, page 67, the desulphurized and not desulphurized mixtures are not nearly close enough to each other to be compared in the effect of desulphurization on the physical properties. If you will note that the silicon in the desulphurized metal is only 1.45 as against 1.90 in the not desulphurized, and the carbon is 3.20 as against 3.25 in the not desulphurized iron. The soda-ash did not effect that change; that was due to a difference in the metal as tapped, so that the strength in pounds transverse and tensile might be higher after the desulphurization than before were it not for the very much softer metal due to silicon and carbon. I think it is well to point that out.

V. A. CROSBY: We have found out that by using over 35 or 40 per cent foreign scrap in the mixture, it effects the shrinkage a great deal. Of course, we run across quite a bit of non-metallic inclusions, etc. We thought iron oxide was included, and we have set 25 per cent of foreign scrap as being the maximum in our particular iron works.

E. J. LOWRY: I think this is a paper which adds to the knowledge in the gray iron foundry. I take exception to what Mr. Mackenzie says, even though the scrap charge was a coarse grade of scrap. Tin is absorbed and is usually a hardener, giving greater strength, as proven by two English writers in *The Foundry Magazine*. I will have to agree with Mr. MacKenzie that there should not have been a dropping off in strength as shown by this paper. The author has stated that malleable scrap is not prevalently used; I believe it all depends on the location you are in. For instance, the author is from Birmingham, and malleable scrap is not prevalent down there; but around Boston and Chicago you will find that malleable scrap is being used rather prevalently as a substitute for steel scrap. I also agree with Mr. MacKenzie that in the pick-up of carbon exception should be made, depending upon the percentage of steel used, the height of the bed and the time consumed in the melting.

The author states on page 56, that the bed must not be very low, that sufficient coke must be used for super-heating and that the common ratio is 7 to 1. That all depends on the foundry you are in and the type of work you are connected with. I do not think that the common ratio would be 7 to 1, because that is the common ratio without steel scrap, and might prove misleading to some of the bosses of the foundrymen who are present here.

This business of scrap is one that has been argued pro and con. Scrap dealers try to please everyone, but scrap is accumulated and then shipped out casually unless you are buying direct from railroads. For instance, if you are a large consumer of scrap, you bid on a railroad list and you are given a preference for a certain grade of scrap. The railroads are very careful in their grading, but if you are buying from a yard what is called a common scrap, then you run the chance of getting a 250-pound piece in a carload, even though your specification says 100 pounds or 150 pounds. No scrap dealer can afford to put scrap under a hammer to break it up to ship it to you at the price you are willing to pay. Several papers were presented before the Iron and Steel Institute in which it was shown that it costs between \$3.50 and \$4.50 per ton to a scrap dealer to prepare the scrap according to the wishes of the user. If the scrap dealer buys from the producer of scrap, say at \$11.00, then he has to put in \$3.50 to \$4.00 to prepare it, that would make it \$14.50 to \$15.00. You can buy pig iron at \$19.00. Under such conditions I do not think you would find there is any economy in the use of scrap at all. It is a matter of opinion, as I have sensed it on my travels throughout the country, that you have to have a differential of between \$4.00 and \$5.00 to make it economical to use scrap in place of pig.

F. K. VIAL: Some 25 years ago I became identified with the car wheel industry, the foundries of which, on account of their peculiar relationship to the railroads, are large users of scrap material. All the old wheels when worn out are returned to the foundry and remelted. Therefore, except in times when there's a large number of new cars being built, we are compelled to use a high percentage of scrap material in our mixtures.

In times of brisk new car building, in addition to scrapped wheels, we use large quantities of other scrap, such as railroad malleable, cast iron or even stove plates, of course, eliminating as was stated in the paper, burned material or defective material.

We follow the lines Mr. Lowry spoke of in fixing a differential; we have an absolute differential between the different kinds of scrap. We fix the unit cost of each element such as iron, silicon, manganese, and apply these values to the composition of pig or scrap. This determines when they can or cannot be purchased from a commercial standpoint. We pay very little attention to the quantity of any of our good scrap; that is, we compound our scrap in such a way that it brings about the product we desire. Now in remelting this scrap from year to year, the sulphur contents grew until it came to a point which we thought was a maximum and steps had to be taken to control the sulphur. Some seven years ago, at the plant here in Chicago, we developed the use of sodium carbonate for controlling sulphur. I believe that we were the first users on a large scale of sodium carbonate or soda-ash for sulphur control. We found that this did the work we expected it to do; it placed the sulphur within our control absolutely. We do not require nor do we desire low sulphur; we consider about 0.12 per cent ideal to make a good sound solid, good-wearing chill. We are melting 300 to 400 thousand tons a year, and we find that this treatment, in addition to sulphur control, actually acts as a refiner and removes some of the occluded gases. This action is continuous all day long on top of our large receiving ladle. All of our work is subjected to severe tests, for every 100 wheels it is required that two be broken for a drop and thermal test, the chill must be maintained within very close limits, so we are melting under close control conditions. Our cupola loss for failure to meet tests is practically nothing. The physical tests have been increased from time to time and we no longer fear the drop and the thermal tests. We almost pass them without notice. Now this is not all due to sulphur control by any means. There has been a marked improvement in the quality of coke, and other conditions have been developed to improve the product. Improvement is going on in all lines of foundry work. The use of scrap is not inconsistent with the highest grade produced.

E. J. LOWRY: Mr. Smith is from Birmingham and probably was at a loss to find out where to get low phosphorus scrap, and probably there are a great many people in the north interested in this proposition of briquetting. You all know about the Dodge Bros. motor foundry using briquetted borings. The General Motors is installing four different briquetting machines in different foundries so that they may use briquetted borings and also turnings. There is also another foundry up in Pontiac which is a rather large foundry, that has installed a machine for the same purpose, so you might not be limited within your territory to get a low phosphorous scrap; you can get briquetted steel turnings and accomplish the same result as by getting malleable scrap of low phosphor.

CHAIRMAN ERB: There is another point that is perplexing to a great many foundrymen, the question of oxidized metal. There are a great many causes for it, but especially the dimensions of the steel scrap used has a great deal to do with it. The author has mentioned one-quarter inch is the limit. In my own experience, we go down as small as one-eighth inch steel, but I did have the experience one time of getting into serious trouble by having lighter steel used, and I personally feel that a lot of trouble exists due to oxidized metal, which trouble even very good foundrymen sometimes fail to recognize.

L. S. SHANNON: Did I understand Mr. Lowry to say that there must be a difference of \$5.00 between pig iron and scrap prices to make it economical?

E. J. LOWRY: No, I said on an average \$3.50 to \$4.00, but generally \$5.00 is considered in certain districts; generally between \$3.50 and \$4.00 makes it an economic proposition to use scrap, that is, from a purchasing standpoint. If you required scrap to produce a casting and this scrap produces losses, you might cut that differential down.

L. S. SHANNON: I want to get what was thought to be the differential there.

E. J. LOWRY: For the scrap, Mr. Smith speaks of, I would say between \$3.50 and \$4.00 in your district.

L. S. SHANNON: The reason I raise that question is because scrap is gradually coming through as a material used in the production of pig iron. There are two points that I would like to get cleared up; whether Mr. MacKenzie thought from his experience that the strength shown in the paper as coming from the use of scrap in the mixture is justified?

J. T. MACKENZIE: Yes, but I figured that in speaking of the influence of tin, the author has compared it in the table with burnt scrap borings, etc., whereas when he used 100 per cent good scrap, he got a very good strength, and that the tin should be compared to 100 per cent good scrap and not 100 per cent burnt scrap, in which case the true influence of the tin is not shown, because I am certain that 5 per cent tin is very deleterious, as I have tried it myself.

R. S. MACPHERRAN: About the strength of an all scrap mixture—we have for about 25 years, run an all-scrap mixture for certain purposes. The strength runs from 21,000 to 22,000 pounds per square inch. I think the parties are talking about different tons. When you buy scrap, don't you buy net tons? We always buy a net ton of scrap and buy a gross ton of pig. We have made castings as high as 50 tons in weight of an all scrap mixture. It machines fairly well in large sections.

W. F. CLEMENTS: In the iron of Table 6, page 67, I think all we use is scrap. We are vitally interested in the difference in Brinnell hardness between the desulphurized and non-desulphurized metal; in the first instance it is 196 and in the second 223. We want to bring out that point.

F. J. WALLS: We have started briquetting cast iron and the Packard Motor Car Company has a small machine. I am inclined to think that you men who are selling your cast iron scrap today for \$6.00, \$7.00 or \$8.00

a ton are losing a lot of money. Our figures show that we are going to pay between three and four hundred per cent dividends on our investment this second year we have that machine in operation.

There has been a question asked about the size of briquet. Those briquets are made under 300 tons' pressure and are 4 inches in diameter and $3\frac{1}{2}$ inches long, and they weigh an average of seven pounds apiece, and have an average density of 80 per cent of the cast iron. No chemical is used whatever.

E. J. LOWRY: I believe there is a lack of information around the country about using briquetted borings. People want to know certain points. Do you have to use any more fuel to use these borings? Do you have to use any higher silicon iron? Do you have to put any more manganese in to use the borings, or do you use these borings directly as scrap?

F. J. WALLS: At the present time we are replacing steel and cast iron scrap by use of borings, but as far as the fuel is concerned, I think you use less fuel.

E. J. LOWRY: I would like to know the difference between the analysis of the average grade of scrap which would be comparable to the average silicon in your compressed borings or your briquetted boring; what would be the difference in the carbon?

F. J. WALLS: I do not think it makes a bit of difference how much carbon you charge into a cupola; you will get a certain amount out. The silicon oxidization losses in your briquettes are not any more than in cast iron. We get an iron oxidation loss on several heats of around 10 per cent of the briquettes. I do not mean over all heats. We are running at the present time about 10 per cent of borings in our mixture.

E. J. LOWRY: Is that melting loss the same as your total loss during your melt, the same with the briquetted borings as with the scrap?

F. J. WALLS: It is proportional.

E. K. SMITH: In using the briquetted borings, did you run a straight heat of borings, and if so, was there any sign of oxidation?

F. J. WALLS: We ran three straight heats and it caused 10 per cent over all loss, possibly 18 to 20 per cent of silicon loss. There was very little sign of oxidation.

DISCUSSION—CORE OIL SPECIFICATIONS

J. A. GITZEN: In regard to the factor of temperature of the solution of the iodine test, does a difference of 10 degrees (70 degrees, instead of 60 degrees Fahr.) increase the iodine number about 15 points? I think you will find that an hour does not make much difference if the temperature is higher by 10 degrees.

V. A. CROSBY: In these checks, all analyses made in the charts were carried out at between 60 and 70 degrees; in fact, most of them were made at the time of the year when that temperature prevailed. So far as the

higher temperatures are concerned, I do not know whether that would make very much difference. When using carbon tetra-chloride as a vehicle, you could not use a very high temperature because of vaporization of the vehicle tetra-chloride. You might be able to put in a refrigerator and try adsorption at a low temperature.

CHAIRMAN ERB: Undoubtedly the detail worked out by Mr. Crosby would be more applicable for a large concern having laboratories such as Studebaker, and I am sure this is interesting to all but men that are so situated that they cannot have such experience as Mr. Crosby has had. We would like to have them enter this discussion.

J. D. STODDARD: I have been very much interested in following the work done by Mr. Crosby of the Studebaker Corporation and am pleased to know that they are getting real results—results that are practical in their application. While the position taken by them and the results obtained have been contrary to that which has been advocated by some of our scholars in the state of Michigan, and other places, who said it was impossible to do what they have done, I feel that they have done a real constructive job, one that the foundrymen of this country can well follow and profit by following.

DISCUSSION—SAFETY AND SANITATION IN THE FOUNDRY

F. BAKER: What rates are some of the foundries paying for insurance?

CHAIRMAN ERB: In our own case, we pay \$1.38 in the Michigan Mutual Company. We get 12½ per cent reduction in premiums each year.

F. BAKER: My rate has been raised twice; \$1.33, then \$1.67, and finally \$2.01.

CHAIRMAN ERB: Our rate was raised recently because the state had given an increased grant to the injured men.

F. H. ELAM: Our company carries its own risk.

T. S. HAMMOND: We carry our own risks; we have gone 81 days without a hospital accident; that includes all the shops.

W. M. MARR: I know that the Ohio Brass Company has been granted a considerable reduction in their rates because of the reduction in accidents they have effected in the last year. We have gone into the safety problem very seriously, and it is reacting on the rates. There has been a considerable reduction in accident insurance cost. In certain departments we have gone since January, 1927, without a lost time accident and none in the entire plant in five months. I might further add that we did run as high as 14 and 15 lost time accidents in a month before we started the safety campaign. Then the plant organized a committee, appointed from among the foremen of the shop, to put over this Safety Campaign. I believe this is a good way to work it. Safety through the shop foremen has worked out very well and it is truly remarkable the results we have obtained in this safety program. Our records show what can be done if anyone really starts out to put over safety in the foundry.

CHAIRMAN ERB: There is a whole lot to safety work and a lot of interest. There is one place that we can reduce our expenses a whole lot, if we will only apply ourselves to the problem.

DISCUSSION—BAKING PRACTICE FOR OIL-SAND CORES

H. L. CAMPBELL: The purpose of preparing the paper on "Baking Practice for Oil-Sand Cores" was to acquaint those foundrymen who are directly responsible for the efficient baking of oil-sand cores with the principles involved in this practice. To aid in a clear understanding of the changes which take place during the baking of cores, the total baking time has been divided into three periods which are designated as the "heating up" period, the "evaporation" period, and the "oxidation" period.

It is well to remember that cores which are bonded with linseed oil are hardened by taking up oxygen from the air. During the baking period, the cores are heated to hasten the oxidation of the oil. Baking temperatures over 425 degrees Fahr. should be used only in carefully controlled practice.

The contents of this paper may be summarized in the following statements:

1. Oil-sand cores may be placed directly in core ovens which are maintained at maximum baking temperatures, without injuring the cores.
2. The total baking time for oil-sand cores may be decreased by using a minimum amount of moisture or volatile oils in the core-sand mixtures.
3. The presence of oxygen is essential to the hardening of oil-sand cores.
4. The length of time at which oil-sand cores are kept at maximum baking temperatures has a critical effect on the strength of the cores.
5. The higher the temperature at which oil-sand cores are baked, the more limited is the range of time over which high strengths can be obtained in the cores.
6. The removal of the gaseous products which are given off during the oxidation of linseed oil is essential to the rapid and complete hardening of the cores.

In order to assist in establishing a better understanding of core-baking practice, it is hoped that through the membership of the American Foundrymen's Association, this paper will be made available to many core-room foremen and core-oven operators.

Report of Committee on Steel Castings

To the Members of the American Foundrymen's Association:

Your committee has this past year discussed a few matters which have been presented to it by interested members.

It has been suggested that some system of numbering the steels used for castings should be adopted, perhaps similar to the method in use by the S. A. E. Your committee, in considering this, came to the conclusion that there is not at present sufficient advantage or demand to justify the proposal.

In the fall of 1927 the A. S. T. M. authorities requested that a special committee be formed to consider the much discussed specification A95-28T, steel castings for valves, flanges and fittings for high temperature service. The special committee was never formed, in spite of the earnest endeavors of its temporary chairman, and finally the secretary of the A. S. T. M. wrote to the A. F. A. requesting that it poll the manufacturers of steel castings for this service and get their opinion upon the revision of the specification as suggested in the plan proposed February 3, 1928, which has been called the Cleveland Compromise and which would change the wording of the process clause to read: "The steel may be made by the open hearth, electric or other process approved by the purchaser," and which makes mandatory the chemical limitations which have previously been included in the specification merely as recommended practice, at the same time raising the sulphur limits from 0.05 per cent to 0.06 per cent.

The questionnaire was sent to all our members who make steel castings, and they were requested to vote upon it, noting whether they made castings for this particular service or not. The questionnaire was, however, worded in such a way that it was made clear that the A. S. T. M. was asking the opinion only of those who actually manufactured castings for this service. Reports were had from 41 companies, 30 of which voted in favor and 11

against the proposed revision. This report was transmitted to the A. S. T. M., and the special committee in charge of this specification voted decisively in favor of the revision and recommended to its parent committee the adoption of the specification thus revised. The parent committee, Committee A1, voted by a large majority in favor of the revision and a letter ballot will now be taken of the entire membership of the committee, the result to be transmitted to the general meeting of the A. S. T. M. in June. It seems entirely certain that the final vote will be quite in accordance with the preliminary votes already taken, and we may consider this much discussed specification as settled for the present at least and for a good time to come.

It has been evident that the manufacturers of these castings have felt the economic pressure of outside specifications and have decided that it was unwise to stand firm for the principle for which we strove so earnestly.

Your committee considers the matter now as closed and wishes to thank you all for the interest you have shown and the support you have given it.

A. H. JAMESON, *Chairman,*
Committee on Specifications for Steel Castings.

Report of A. F. A. Representative on Joint Committee on the Investi- gation of Phosphorus and Sulphur in Steel

To Members of the American Foundrymen's Association:

Your representative on the Joint Committee on the Investigation of Phosphorus and Sulphur in Steel is glad to report that the physical testing of the cast steels to ascertain the influence of phosphorus on that material is in progress. The data so far secured are as yet too incomplete to justify publication of the results at this time.

The fact just stated makes it impossible to add anything of value relating to this subject to what was reported at the last A.F.A. convention, when detailed information was given as to the manufacture and heat treatment of the cast steels made for tests to ascertain the influence of phosphorus.

Dr. G. K. Burgess, Chairman of the Joint Committee, recognizing the great interest of steel foundrymen in this subject, will take such steps as he consistently can later, to put the results of the phosphorus steel casting tests at the disposal of producers of steel castings generally at as early a date as may be consistent with all the circumstances.

Respectfully submitted,

R. A. BULL,
A.F.A. Representative
On Joint Committee on Investigation
of Phosphorus and Sulphur in Steel.

DISCUSSION

R. A. BULL: I might say, supplementing my report, that recently I received a letter from Dr. Langenberg, chairman of the sub-committee on

tests, indicating that very recently more progress has been made for a number of months, and I think it is possible that the results of at least some of the tests might be announced at the testing society convention to be held the latter part of June. I believe that more progress would have been made if the government had had appropriations that might have been utilized for the purpose at its Watertown arsenal.

You may remember that the steels were made something like a year ago at the Atlantic Steel Casting Company. It seems at least reasonable to assume that by fall, if not by the middle of summer, the results of the tests of those cast steels will have been announced in some way, probably through the A. S. T. M. convention.

Steel Founding Session

Two papers and two committee reports were presented at the session on Steel Founding. The report of the Committee on Steel Castings will be found on page 626, and the report of A. F. A. representative on the Joint Committee on Investigation of Effect of Phosphorus and Sulphur in Steel appears on page 628. The paper by D. Zuege on "Alloy Steel Castings" will be found beginning on page 361, and that by F. A. Lorenz, Jr., on "Efficient Steel Casting Grinding" begins on page 199.

DISCUSSION—ALLOY STEEL CASTINGS

WRITTEN DISCUSSION—SUBMITTED BY A. N. CONARROE*

I have read Mr. Zuege's paper with much pleasure and think that he has added a real contribution to the subject of alloy steel castings, about which the published data are meager.

It seems that most manufacturers have been loath to publish data on their alloy steel practices, rather from a feeling that their data represented local conditions and not the best, which could be expected from a given composition, than from a desire to keep the data secret.

It seems to me that this is a mistaken idea and that a real knowledge of the properties obtainable from different alloy combinations and treatments can result only from a compilation of data from a broad field, representing actual service conditions.

Mr. Zuege shows the better results obtainable with the more costly combinations of alloys and wisely suggests that a study should be made as to the availability of the lower priced combinations for any particular case. In this connection, it should be mentioned that water quenching of the manganese-carbon compositions, shown by Mr. Zuege as oil quenched, will increase the tensile strength.

One of the chief benefits to be obtained by a compilation of data on alloy steel castings will be its value to the designing engineers. When studying data such as appears in Mr. Zuege's paper it must be borne in mind that the results obtained were upon specimens of small cross section. It would be unreasonable to expect these values to exist throughout the entire cross section of a larger diameter.

The oil quenched results of the small sections would partially duplicate the results obtainable by water quenching castings of greater cross section.

On the carbon-manganese steels mentioned by Mr. Zuege, there is a very close linear relationship between the Brinell number and the ultimate

*National Malleable and Steel Castings Co., Chicago.

strength. There seems to be also a linear relationship between the Brinell number and the elongation, the elongation falling however, in a faster ratio than the increase of the ultimate strength for the same increase in Brinell number.

By determining the Brinell number across the section of a casting and remembering that the corresponding ultimate strength represents an area proportional to its distance from the center, an average ultimate load value can be computed. It is possible that this may also hold for other compositions, and data along these lines would be valuable to designing engineers.

The point about cleanliness when manufacturing alloy steels consisting of a mixture of alloying agents is well taken. These steels are generally very prone to dendritic segregation during the freezing in the molds with the resultant deposition of the foreign material along dendritic grain boundaries. Once deposited in this position, no heat treatment will reabsorb them, the steel being extremely tender and many times actually brittle.

I hope Mr. Zuege's contribution will call forth an extensive discussion, especially after the present convention; and will be followed by the publishing of reliable data on the subject of alloy steel castings concerning the entire range of sections found in commercial castings.

A. W. LORENZ: Mr. Zuege's object, as stated in the last paragraph of his paper, is certainly commendable, namely, to present data on the physical properties of alloy steels, so that in time we may gather enough of that information to be able to have some really valuable knowledge as to what the steels will actually do.

About a year ago a subcommittee of one of our technical societies attempted to draw up some tables showing the comparative properties of various types of alloy castings. After a very short time we found that it was entirely impossible to do this on account of the dearth of information. As Mr. Zuege states here, it is only through papers such as this that we will be able to get that information.

As I read over the physical properties shown in the paper, it was interesting to me to note how closely those results compared with our own on some of the types which he mentioned. On the 1.20 to 1.60 per cent manganese steel, for instance, an average of 85 tests which I took from our files just before coming out here showed a yield point of 55,206 pounds, which is only about 200 pounds different from the average shown by the tests which Mr. Zuege has submitted. The ultimate strength is somewhat higher than his results, just a few thousand pounds. The elongation and reduction are lower, but not much. The elongation average that we show here is about 25 per cent and the reduction about 45 per cent.

There is one point I noticed in the comparison between chrome-nickel steel and the 1.20 to 1.60 manganese steel. Mr. Zuege makes the statement on page 375 that "—It may be noted that the normalized and drawn chrome-nickel steel has slightly higher values for yield point and tensile strength than the normalized manganese-carbon steel, but also has considerable less ductility." I think it would be fair in making the comparison

of different types of alloy steels to compare them on a basis of equivalent analysis. That is to say, the manganese-carbon steels which are shown have a carbon content of about 0.33 per cent as I averaged them and the chrome-nickel steels seem to run around 0.40. Now, I realize that 0.40 carbon-nickel-chrome steel is a standard product in many foundries, but it seems to me that you really ought to compare them on a basis of equivalent carbon. Now, I have done that and our figures show that with nickel-chrome steel averaging 0.32 carbon, an average from about 75 heats, and the manganese carbon steel averaging 0.33 carbon, and 1.35 manganese, we have a yield point of 65,500 pounds for nickel-chrome steel as compared with 55,000 for manganese-carbon steel. We have an ultimate of 103,000 pounds for the nickel-chrome steel as compared with 92,000 pounds for the manganese-carbon steel. The elongation on the nickel-chrome steel is 22.3 as compared with 24.7 for the manganese-carbon steel, or in that respect the nickel-chrome steel is slightly lower. On the reduction of area we have an average of 47.9 per cent for the nickel-chrome steel and 44.6 per cent for the 1.20 to 1.60 manganese steel.

I do not say this to deprecate the value of manganese-carbon steel, because it is so much cheaper than the nickel-chrome steel that they aren't in the same price class at all, and for the cost of the manganese-carbon steel it is a very wonderful product. But I think these data ought to be brought to the attention of the persons present, because in our plant we have a warm spot in our hearts for nickel-chrome steel. We have been making it for many years, and probably simply because we have been making it for so many years we are getting a little better results on it than we would with a steel which we haven't been making for such a long period of time.

A. C. JONES: I want to publicly compliment Mr. Zuege on this fine paper. I think that, as he has stated, our literature has been lacking in such type of experimental evidence. I can confirm pretty well what he has said about the use of manganese-molybdenum steel. We haven't used it with the additional percentage of nickel of one per cent, but about three years ago we experimented on manganese-chrome-molybdenum steels for foundry casting purposes. We have been making it for about a year now with very good results. I am sure that anybody who does use it will find that it does exactly what Mr. Zuege says. It makes it possible to get castings of very high physical properties without the necessity of a liquid quench, which, as he has stated very well, brings danger from unequal sections and also very sharp corners.

We have a great number of combinations of alloy steels which probably have been specified from time to time by the users of alloy steel castings, and I believe all of us are somewhat confused as to when nickel-chrome should be used, when chrome-vanadium should be used, or when vanadium steel alone should be used. The molybdenum-manganese-chrome-nickel steels and also the manganese-molybdenum-chrome without nickel, give the foundry an opportunity of getting the very high physical characteristics without the danger that might be expected with some of these

other steels which probably depend in the forged and rolled industry on liquid quenching.

A question which I would like to have answered, if possible, is, to what extent is vanadium a cleansing or deoxidizing agent? Mr. Zuege has mentioned that it has been claimed for vanadium that it is a degasifying agent, but I have not found that to be true in some cases. In other words, it may degasify, but not to a very great extent.

A. H. JAMESON: Mr. Zuege, is it permissible to give us the other constituents in these steels that are mentioned? In table 10 on page 378 the carbon content is mentioned but the content of manganese, chromium, nickel and molybdenum is not mentioned.

D. ZUEGE: Steps have been taken to secure a patent on this steel. Unfortunately, at the time that the paper was written, those steps had not been taken, and for that reason the values were not included in the paper at that time. We attempt to keep the carbon between 0.30 and 0.40; the manganese from 1.25 to 1.60; the chromium from 0.75 to 1.0; the nickel from 1.0 to 1.5, and the molybdenum from 0.30 to 0.40. I regretted that at the time of writing the paper these steps had not been taken and that it therefore made it necessary for me to omit the composition of the steel.

C. E. SIMS: I wish first of all to commend the author's motive in getting a wider dissemination of information as well as his orderly arrangement and classification of the physical properties of alloy steels. The literature does contain a woeful dearth of information regarding the properties of cast alloy steels and also steels of all classes in the normalized state. Individual organizations no doubt have a good deal of information, but their information is necessarily incomplete, and the purpose of this paper is laudable.

In this paper you will notice a great variety of physical properties among the different steels, and you will also notice that among different steels you will find bars of similar properties. But you will also find that these steels have obtained these similar physical properties through different heat treatments. The significant fact there is that each of these steels has some particular use for which it is better fitted than most of the others. Of course, no steel is complete until it has had an appropriate heat treatment. I want to emphasize the point very strongly, that the heat treatment of an alloy steel casting is the making of the casting. The alloy additions might be largely wasted unless the proper heat treatment is given.

The selection of the best steel is a job for the foundryman, the designer and the user of steel castings, and it will be controlled by such conditions as cost, cross section, shape, and the nature of the service to which it is to be put. Cost is never an inconsiderable item and there are times when the more expensive alloy additions will not pay their way. For instance, in Table No. 7 we find the properties of nickel-chromium steels, and in Table No. 2 on page 367 the properties of the carbon-manganese steels. If we will note the best steel listed in Table 7, which is No. 8, with a yield point of 70,400 pounds, tensile strength of 110,500, elongation of

20.5, and reduction of area of 33.5, and compare it with the best steel in Table 2, that is, Heat 098, we find in the latter a trifle lower yield point, equal tensile strength, and better ductility. I must say, however, that Mr. Zuege has been conservative in his appraisal of the carbon-manganese steel. For instance, if we go to a slightly higher carbon as, for illustration, the steel with a composition of carbon 0.44, manganese 1.45, silicon 0.34, the yield on duplicate bars was 73,250 and 72,500; the ultimate strength 109,250 and 109,050 pounds; elongation in both cases, 27 per cent; reduction of area was 51.9 and 53.6 per cent, respectively. There we find that in all properties it is superior to the nickel-chromium steel in a normalized and drawn condition.

The author has intimated, however, that nickel-chromium steel shows up to its best advantage when quenched and drawn to a higher hardness. In this respect compare bar No. 5 in Table 8 with a carbon-manganese steel that has been water quenched and drawn at 650 degrees. This latter steel was selected because it had the same hardness, namely, 387 Brinell. Its composition is carbon 0.41, manganese 1.53 and silicon 0.47. Where the nickel-chromium steel had a yield of 149,000 pounds, this carbon-manganese steel had a yield of 166,800 and 166,100 pounds. Where the chrome-nickel steel gave an ultimate of 182,950, this steel gave an ultimate of 181,200 and 186,000 pounds. The elongation was 10 and 8.5 per cent as compared to 8.5 per cent in the former. The reduction in area was 26.6 and 21.2 per cent as compared to 18.4 per cent. In every respect, therefore, the properties are higher than in the nickel-chromium steel.

Figuring from these data alone, one might argue that the carbon-manganese steel is the superior steel, but my object is not to show the superiority of one steel over another but merely to indicate that it is not an easy matter to choose the correct steel for any class of service. Where the carbon-manganese steel might be entirely unsuited, the nickel-chromium steel perhaps would fit perfectly, and Mr. Zuege has shown the type of work in which the chrome-nickel steel is superior. There will be no need to repeat that.

His discussion of the air-hardening steels is very interesting and the advantages of an air-hardening steel in castings that will not allow of water quenching are too obvious to the foundryman to need discussion. But we surely do need more information on all of these steels.

A. W. LORENZ: I would like to emphasize in comparing alloy steels, that you can't compare alloy steels, especially in the harder grades, on the basis of one or two tests. You can't select individual tests and say, "Here, this shows that this steel is better than another steel." You have to have a large number of tests and average them up before you get anywhere, for when you get into your higher grades, one of the first things that you encounter is the fact that you have to have a testing machine which is in absolutely accurate alignment, otherwise those bars are going to snap. You take a low carbon steel and it doesn't matter if the testing machine is out a little bit, the bar will just bend and adjust itself to the load.

Another point is that apparently in the higher alloy types and in the harder types the least bit of impurity affects the results very largely, especially if you may take one test bar by itself. We generally take a test bar about 15 inches long and then cut three tests from that and thereby we get three samples of the one piece of steel, and in a piece of hard metal, even then those three tests will vary greatly unless you are very careful. It shows that the least bit of impurity that gets in will bring the ductility values down to a very low point. I think that is one of the most important reasons for getting as much of this information together as we can from the various sources, so really in time we can arrive at a true average.

F. A. LORENZ, JR.: Personally, a great many of us here are on the other side of the fence, we are on the receiving end and we have to manufacture these castings in the foundry. I am just wondering how many of those present had the same reaction to the paper that I had. The users of alloy castings are groping around and they first want you to make one casting. Foundries aren't organized, at least very few of them are, to turn out one experimental alloy steel casting. This is particularly due to the size of the heats which they necessarily have to make to meet the regular routine of the foundry which has already been established for their class of work, and the lack or the unsuitability of their present equipment for proper heat treating and processing the casting clear through the foundry. So I think the industry is absorbing enormous costs which are not as yet passed on to the consumer in the manufacture of alloy steel castings. At least, that is my personal experience in operating foundries to attempt to satisfy the user of alloy steel castings.

There are other groups who are manufacturing alloy steel castings for their own use, who have determined certain specifications for their castings, and are fully equipped to manufacture those castings. I think they speak with authority when they say that the cost is not in the alloys put in the casting alone but it is in increased proportion all the way through the foundry resulting in large increases in production cost.

Perhaps one of the greatest losses in a miscellaneous foundry making all types of castings is the fact that it so greatly interferes with the regular flow of production and slows up processes and increases the loss to such a great extent that it is very doubtful in the present state of the industry whether the one experimental alloy steel casting can possibly pay its way.

I am just sounding that note more particularly from the viewpoint of the user of the alloy steel casting expecting unusual service on a very small lot of castings from the average foundry which is not equipped to produce the casting in accordance with practices which produced the results as shown by the research of the metallurgist. The alloy casting is a wonderful work and eventually it will come into its own.

I have talked with many men in the research groups and a great many of the foundrymen and I think that sums up their experiences. If I am wrong, I would like to be corrected, but to a practical foundry-

man, that is the other side of the picture and I can't help speaking of it when the opportunity presents. It is so in grinding, it is so in machining, it is so in heat treating, it is so in all the cleaning operations, the slowing up, the extra care and the extra cost to which you are put to produce the desired result in the particular type of casting ordered.

DISCUSSION—EFFICIENT STEEL CASTING GRINDING

F. A. LORENZ:—A grinding wheel test was made from January 9th to 12th, 1929 (inclusive), to determine whether or not there was a difference in operation and cost between the vitrified bonded grinding wheel and the vegetable bonded grinding wheel.

The vitrified bonded grinding wheel was a 30-inch diameter wheel with a $\frac{3}{4}$ -inch per foot safety taper on the sides.

The vegetable bonded wheel was a 30-inch straight side type 12-inch center.

Methods Used in Test

The test was made on two different types of grinding machines.

The vitrified wheel was tested on a belt driven, dual entry, grinding machine.

The vegetable wheel was tested on a direct motor driven, single entry, grinding machine.

One operator was used on both wheels, thereby doing away with the variable of the human element. The operator was allowed to grind as he pleased; in other words, he was given no instructions as to just when or where he should use the pinch-bar, oil or excessive pressure. The conditions and results are, therefore, representative of the practice that would be in use if either of these machines and wheels were used exclusively in the cleaning room.

The same number of castings having the same pattern numbers were ground on each wheel. This eliminated any variations due to the type, weight, size or design of the castings.

The element of fatigue was also considered. An operator works slower as the day progresses. The tests were, therefore, made with the operator working one hour on one wheel and the following hour on the other wheel, so that his fatigue would be equal on both wheels.

A scale was used for each wheel. The scales were set on platforms that were leveled each day with a carpenter's level. The scales were adjusted after every load. These precautions are very necessary when one considers that the amount of metal removed from a casting by grinding averages between 0.2 and 0.3 of one per cent. Never less than 5 castings or 350 lbs., were placed on the scales on any test. This gave the minimum increment of weight, which was $\frac{1}{4}$ pound, a smaller chance to increase the per cent of error. The smallest amount of metal removed on any test was $2\frac{3}{4}$ pounds, which makes the possible per cent error about 5 per cent as a maximum.

Any pause of over 30 seconds was subtracted from the grinding time. This made the per cent error in the grinding time almost negligible.

*Explanation of Results in Data Sheet
Speed*

The speed of the direct drive grinding machine is approximately 400 r.p.m. greater than the belt driven grinding machine. The belt driven machine could easily be increased 400 r.p.m. by the use of different sized pulleys, but the vegetable bonded wheels could not be used in this case on account of the excessive vibration on the belt driven machines. The vitrified wheels cannot be run over 6,000 feet per minute with safety, while the vegetable wheels can be run safely at 9,000 feet per minute (peripheral speed). Therefore, it would be impossible to put a vitrified wheel on the direct drive machine unless the speed was reduced considerably. As the vegetable bonded

Table 1

**COMPARISON OF A VITRIFIED BONDED AND VEGETABLE BONDED
GRINDING WHEEL**

Wheel Bond	Wheel Size	Speed of Machine	No. of Castings Tested	Total Wgt. of Castings After Grdg., Lbs.	Avg. Weight Castings, Lbs.	Vol. of Abras. Avail., Cu. In.	Diameter of Wheel End of Test
Vitrified...	30x2½x2½	765	203	17,546	86.5	1966	28¾
Vegetable...	30x3x12	1151	203	17,424½	85.9	1590	28¾

Wheel Bond	Abras. Rem'd, Cu. In.	Wheel Cost	Cost Per Cu. In. Avail.	Metal Rem'd, Lbs.	Metal Rem'd, Cu. In.	Cu. In. Metal Rem'd Per Cu. In. of Abrasive,	Lbs. Metal Rem'd Per Cu. In. of Abrasive, Lbs.
Vitrified....	176	\$42.98	\$0.0219	103.25	365	2.07	0.59
Vegetable...	228	68.33	0.0430	120.50	425	1.86	0.53

Wheel Bond	Cost of Abras. Rem'd	Grdg. Time, Hours	Metal Removed Per Hr., Lbs.	Labor Cost @ 50 Cents Per Hr.	Over-head	Total Grdg. Cost	Cost Per Lb. Metal Removed
Vitrified....	\$4.54	11.90	8.67	\$5.95	\$4.46	\$14.95	\$0.1445
Vegetable...	9.80	8.23	14.64	4.12	3.09	17.01	0.1412

wheels remove a greater amount of metal per hour than the vitrified wheel, it would be a loss to place the vitrified wheel on the direct drive grinding machine.

Castings Tested

There were 203 castings tested on each wheel with an average weight of 86 pounds per casting. All types of castings were used so that the results are indicative of highly miscellaneous work.

Grinding Wheels

At the end of the four-day test the vitrified wheel had reached a diameter of 28¾ inches or a loss of 176 cubic inches of abrasive. The vegetable wheel had decreased in size to a diameter of 28¾ inches, or a removal of 228 cubic inches of abrasive. This would indicate that the

vegetable wheel was the softer, but when one considers that the vegetable wheel is traveling at 33.5 per cent greater speed, the above conclusions would not be made.

Wheel Cost

The cost of the vegetable bonded wheel per cubic inch of abrasive available is exactly double the cost of the vitrified wheel.

The cost of the abrasive removed during the test was, therefore, over double for the vegetable bonded wheel.

Metal Removed

The data sheet shows that the vegetable bonded wheel removed 14.6 per cent more metal off of the same kind of castings.

The vegetable wheel is much less fatiguing to the operator than the vitrified wheel, and in comparison it is really a pleasure to grind on the vegetable wheel. An operator will, therefore, grind off small nail heads or any other irregularities that might present themselves to view while grinding on the vegetable wheel, but on the vitrified wheel where it is so much harder work he will grind only that which is absolutely required.

An operator working on the vitrified wheels gets in the habit of grinding a certain casting a standard way, that is, he passes the casting a certain number of times across the wheel to remove a fixed amount of metal. When he grinds on a vegetable bonded wheel he makes the same number of passes and in doing this would remove 40.7 per cent more metal, as the results show.

The results also show that one cubic inch of abrasive removed 2.07 cubic inches of metal on the vitrified wheel, while the vegetable bonded wheel removed but 1.86 cubic inches. As before mentioned, the comparative speeds of the machines prevents one from drawing any conclusions from these figures. However, if speed was neglected, it would point out that the vitrified wheel was either harder or the grinder used more pressure in grinding.

Grinding Time

The grinding time showed that it took 31.1 per cent greater time to grind the same castings on the vitrified wheel than it did on the vegetable bonded wheel. The causes for this are:

1. The vegetable bonded wheel will remove metal 40 per cent quicker than the vitrified wheel.
2. The operator used the pinch-bar whenever possible on the vitrified wheel, but only when a large piece of metal confronted him on the vegetable bonded wheel. Consequently he did not have to stop to pick up his pinch-bar several times while grinding a casting.
3. The operator used oil on the heads of the castings on the vitrified wheel, but not a drop of oil was used on the vegetable bonded wheel. This also saved time and oil.
4. It happened on two different occasions that the belt was slipping on the machine driving the vitrified wheel, which caused the operator to

exert pressure and when the wheel slowed down, wait for a few seconds until it could regain its speed. This took very little time comparatively, but goes to show the inconveniences connected with the belt drive.

5. The greater peripheral velocity of the vegetable bonded wheel.

6. Less vibration. A wheel that is out of round throws the castings off of the wheel, thereby giving contact only part of the time, to say nothing of the strain on the grinder. This is what happens on practically all of the vitrified wheels on the belt driven grinding machines, and does not occur on the direct driven machines.

The labor charges taken at 50 cents per hour and the overhead expense at 75 per cent of the labor charges are also 31.1 per cent greater on the vitrified wheel. This is supposed to make up for the double cost of the abrasive per cubic inch on the vegetable bonded wheel, but it only decreases it 31 per cent. The rest must be made up in the amount of metal removed.

Final Results

The vegetable bonded wheel removed 6 pounds of metal per hour more than the vitrified wheel, or an increased rate of 40.7 per cent. This is due to the rubber wheel removing 14.6 per cent more metal in 31.1 per cent less time.

The total grinding cost, with the comparatively high priced vegetable bonded wheel, is \$2.06 greater for the rubber wheel, or 12.1 per cent greater than the total grinding cost of the vitrified wheel.

The cost per pound of metal removed is approximately the same. The \$2.06 difference in total cost is equalized by the 60 additional pounds removed by the vegetable bonded wheel.

This cost per pound of metal removed is $3\frac{1}{2}$ cents cheaper than any stand grinding wheel yet tested.

Conclusions and Recommendations

Although the unit cost is the same, the vegetable wheel would have the following advantages:

1. Castings could be ground in less time, thereby speeding up production.
2. The rate of fatigue of the grinders would be decreased, which would enable them to maintain a higher efficiency through the day, and still be more rested at quitting time.
3. The use of the direct drive grinding machines which would eliminate the overhead auxiliary equipment and thus improve the appearance of the cleaning room.

If the direct drive grinding machines were installed the rates could be cut 30 per cent and the grinders would still make the same daily wage.

F. A. LORENZ, JR.: I might remark that we omitted the wheel changes, as they are necessary in this type of machine, but the wheel changes on one machine doing the work of six are so much less that it is practically a negligible factor, although it should be taken into consideration and given credit

Since that paper was written, we have performed further tests and as a result are laying out another grinding department. The results of tests which were given were on swing frame practice. It naturally followed that if it worked out on swing frame practice, it might be well to run a test on stand grinders. Such remarkable strides have been made in the design of the stand grinding machines, either the double end or single end type, largely following the first results which were obtained by high-speed swing frame grinding, that we concluded that we should make a test of that type of grinding machine.

The test was made on two different types of grinding machines. The vitrified wheel was tested on a belt-driven, dual-entry grinding machine. The vegetable bonded wheel was tested on a direct motor-driven single-entry grinding machine. One operator was used on both wheels.

Too often people, in looking at this, simply look at the wheel cost per pound ground and forget about all of these other important factors which must be so closely watched.

The actual results of these tests are rather voluminous, but I might give you some of the results. While the cost of metal removed in the case of vitrified wheel was 14.45 cents per pound, the cost per pound removed with the vegetable bonded wheel was 14.12 cents. In other words, for all practical purposes the cost per pound removed is very nearly the same. But the rate of the speed or the rapidity with which it is removed with one machine is about three times as fast as the other, or doing the grinding in about one-third the time at a 30 per cent reduction in labor cost. These factors are the big factors to be considered. In other words, it is the same thing if you take a high-speed lathe; it will do the work in one-third the time of the ordinary engine lathe, and that is about the nearest comparison that can be made to these two types of machines.

E. H. BALLARD: I think that is a very fine paper given by Mr. Lorenz. Recently, we have been working on this same subject and, in general, I would say that the conclusions which the speaker has indicated in his paper as to the relative merits of one wheel as compared with another are absolutely borne out by our tests. There is one thing, however, in testing stand grinders, that he hasn't mentioned. I am wondering what was the duration of that particular test. That is to say, was it sufficiently long to have reduced the diameter of the wheel appreciably?

F. A. LORENZ, JR.: Yes, we have carried that out to finality, we have gone all the way through on the tests, and with more than one wheel.

E. H. BALLARD: The interesting thing to me is, it brings it back to a still further refinement of the grinding wheel. That is the maintaining of the peripheral speed. We have found that there is a declining efficiency, naturally, as the wheel reduces in diameter. What we hope to do is to maintain the peripheral speed by a change in the speed as the wheel reduces in diameter.

F. A. LORENZ, JR.: There are two sides to that question which have been taken care of by the designers of the stand grinding equipment for

high-speed wheels. The variable speed, direct current motor with safety devices will increase the speed of the motor and, consequently, the peripheral cutting speed of the grinding wheel as it decreases in diameter. That may be permissible with certain companies. Other companies feel that the safety factor of the increasing speed of the direct current motor has not been made sufficiently fool-proof to install it in their plants. In other words, there is danger of improper operation, of speeding up the wheel beyond its safe limit by tampering with the devices which have been applied to the machine for automatically increasing the speed with the decrease of the diameter of the wheel. Others have sufficient machines so that the speed changes will take care of the decreasing diameter of the wheel by wheel removal and applying them to other constant speed machines, running at increasing R. P. M. In other words, as shown in that table, you would have four machines with constant speeds, and as the wheel wore from 24 to 22 inches or from 30 to 28 inches, they would be changed to another machine. One man would have charge of your wheel changes, thereby eliminating the danger of the direct current motor becoming over-speeded, either unintentionally or otherwise.

This test on the stand grinder was run for a duration of three days, constantly taking these observations, but the indications were the same as they were with our swing frame grinders. The results of actual practice, due to improvements and further study of the type of wheel which we are using, and perfecting of our handling to and from the machines, has reduced the actual cost from around eight cents to seven cents, or 12.5 per cent further reduction in cost than originally indicated by the tests. It will probably be the same in this other class of work.

H. P. EVANS: We have been carrying out an investigation that probably lasted a little longer than the speaker's, running several hundred tons of manganese steel each month. We wish to substantiate most of the details that were mentioned. We have also tried the constant peripheral speed as against the staggered, carried it down in both cases to nine inches from a 24-inch wheel to a 9-inch wheel. We find the 9,000 to give you considerably better results than the 6,000. We have found very little difference in changing five wheels on the constant speed grinders to maintain the constant peripheral speed. We naturally find as the wheel gets smaller and the peripheral speed remains the same that the amount of material removed, with the same peripheral speed but a smaller wheel, gets considerably less. While we haven't carried it far enough to know if it might be true, we are wondering if a smaller wheel should be run quite so fast. You get a different kind of a contact on a big wheel than you do on a smaller wheel, you get more of a bite. We have not carried that far enough to arrive at any conclusive figures on it, although the wheel people say you should keep the speed up to 9,000 regardless of the size of the wheel, although it seems that the slower speed may be just as good on the smaller sizes.

F. A. LORENZ, JR.: We have come to the conclusion on running grinding wheels, no matter what type they are, that when they get down

to small diameters their performance is quite inefficient. We have found it greatly to our advantage to use 30-inch wheels and run them down to not less than, say, 15 inches, that from 15 inches down the decrease in efficiency of any type of grinding wheel is so marked that it doesn't even pay you to put them on a machine to use them up to stubs. It is cheaper to throw them out; break them up and salvage the lead liner than it is to try to run the small wheels for production work. There may be some places where they might be used up and gain some advantage, but for production work, where you have to produce the castings and get them through the cleaning room, it is very much to your advantage to keep to the larger diameters if at all possible.

T. H. TREVITHICK: Along the line of changing of wheels, we are making tests in our cleaning room and we have developed a special shaft to contain the wheel. Of course, the manufacturers of wheels are always ready to make a special wheel, and the rubber bonded wheels being used can be made to any desired size and dimension. We have put a special head on the shaft itself, and we have reduced the diameter from 24 to 15 inches. We discard the wheel and we leave about one inch of the abrasive, so the abrasive is very much increased and our efficiency is very much increased because we don't have the changes on the wheel itself.

M. W. POHLMAN: I have followed the development of high-speed wheels for the last six years as applied to portable wheels in the foundry and I find quite a marked increased wheel loss on the new wheels, wheels that are not aged. Although the manufacturers disagree as to how much this factor of aging affects the increased cutting life of the wheel and the rapidity of the cut, I still think there is quite a marked difference there and I think that over the next year might be one thing that you might watch as affecting your large wheels.

Non-Ferrous Metals Session

Three papers were presented before the Non-Ferrous Metals Session. One by R. J. Anderson, G. E. Hughes and M. B. Anderson on "An Open-Flame Hearth-Type Furnace for Melting Aluminum and Its Alloys" was read by title and will be found beginning on page 153. The paper "Electric Arc Furnaces in a General Jobbing Brass Foundry," by J. B. Meier, will be found beginning on page 305. The third paper was presented orally as reproduced below.

Chairman G. H. Clamer in opening this session first called upon H. J. Roast, of the National Bronze Company, to give his paper on Some Practical Problems of the Brass Foundry. Mr. Roast's paper was presented as an informal discussion as given below:

SOME PRACTICAL PROBLEMS OF THE BRASS FOUNDRY

H. J. Roast:* I feel sometimes that when we are listening to a speaker, one of our interests is as to what extent his experience is duplicating our own, and that will be my apology, for, in a very brief way, citing some examples of casting problems encountered in our foundries.

We are melting in our brass foundries something like two to three hundred thousand pounds of bronze a month, pouring it in to castings varying from possibly five or ten pounds up to five thousand pounds. In addition to that, we are melting bronze for architectural purposes, some very fine light work and some larger work.

On the question of some practical problems in the brass foundry, I want to ask your patience, because they may seem so very simple. I have taken the liberty of talking about the everyday practice in the foundry and I propose to cite four examples. One example is in connection with the question of separation in a phosphor-bronze alloy upon fracture; another in connection with white metal alloys required sometimes in architectural work, and which the brass foundryman may be called upon to handle for pouring in sand, another the very elementary metallurgy, perhaps, in the making of a simple buttonhook and yet which brings out general foundry principles, and lastly the casting of a bronze door, in size about 13 feet by 4 feet, a quarter of an inch thick.

The first problem of which I wish to speak is the separation upon fracture of a phosphor-bronze alloy. The alloy contains 11 per cent tin, and $\frac{3}{4}$ of a per cent phosphorus, that is, by analysis after cast, and the balance copper. I cite this example because there may be foundrymen here who run up against the difficulties of loss of castings by not meeting

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specifications due to analysis and physical tests, to which tests they have to bow absolutely. Then if they refer to their officers, they are told that such and such a laboratory has made a test and that the casting does not come up to specifications, therefore they have to make another casting and it is all their fault.

Checking Chemical and Physical Properties

It isn't always the foundryman's fault that his castings apparently do not meet the specifications and this is a specific case that I wish to instance. The first trouble in this case was that we were told by the customer's chemist that the phosphorus content was 0.56 instead of 0.7 per cent. We then took up the matter and sent out samples for check analyses both to the United States and Canada, and received, I am sorry to say, a variety of test results. In connection with these differences, after finally running each one down as far as we could, we got an agreement on a figure of 0.7 per cent, which was the figure originally put out by the laboratory of our own foundry. That cleared up the matter of the analysis.

Then we had the Brinell figure to contend with. This was supposed to be 70 Brinell on the machined casting. Now, we are all familiar with the Brinell tests, and I don't wish in any way to suggest that the Brinell isn't a satisfactory test, because it is. I wish, however, to draw attention to the troubles of the foundryman when he meets with tests made on Brinell machines that may not be kept in the order in which the original maker intended they should be kept. In this instance, anyway, we had a Brinell figure of something like 48 for the lowest and around 57 for the highest, made, not by the chemist, but the engineer of the customer. Our own figure was around 70 or 72. We sent out the bar to various people and received a variety of results from outsiders as well as those immediately interested.

We then made up a bar consisting of 8 per cent tin and the balance copper, with very little phosphorus for purposes of deoxidization and not sufficient to form a phosphor-tin compound, and did our best to get a uniform bar, with the results that the bar went 45,000 pounds in strength, 22,000 pounds in yield point, and 56 per cent elongation. We felt that these figures indicated a sound metal and we found further that when we sent these bars to the various Brinell testers, we got uniform results with the exception of our customer. We weren't satisfied, so we went further and secured a standard steel bar running Brinell about 310 and sent that out to everybody. We all agreed, including the customer. It would therefore appear that there was something peculiar about the test made on the customer's Brinell machine that had to do with soft metals and which did not show up on hard metals.

Bearings Separate in Layers

Now, perhaps the most interesting problem feature from the metallurgical point of view which I have to cite is that of separation. In this case certain bearings were about eight inches long and three-eighths inches thick,

and in diameter about five or six inches. One of the tests was the fracture test. When you broke these bearings, two layers, with the dividing line practically in the center of the cross section, opened up almost sufficiently to cause the casting to fall into two pieces. The questions of general oxidation, of impurities, etc., all suggested themselves to the foundryman and an investigation was started.

While the investigation in the foundry was going on, we took samples for macrographic and microscopic examination. To the practical man who sometimes thinks that the microscope is an unnecessary addition, I want to say that I don't agree with him. I think that it has been abused, too many photo-micrographs are put out that are pictures and have very little practical history. In this instance we took macrographs at ten diameters, which often tell you much more than the high powered photomicrographs. We also discovered that there was a standard bearing of the type involved in this discussion made in Europe, and on taking the European standard, we found that the metal part was not entirely sound, in fact, very far from that. It didn't separate on fracture but it did have a considerable number of voids and a very large dendritic structure. We cast our own bearings at temperatures of 2100 to 1900 degrees Fahr., respectively. That is to say, we started pouring with a pot of metal at 2100 degrees and then continued pouring these castings to 1900 degrees. We then broke one bearing out of each flask and found that until we reached 1900, the separation was marked and distinct. When we cast below 1900, the cross section was uniform and the metal entirely sound.

The reason for it was explained by the macrophotographs, which showed a very large dendritic structure at 2100, at 2000, and at very close to 1900, the dendritic structure naturally getting somewhat smaller, and these large dendrites fitting in only very loosely. When the two chilled surfaces of the bearing solidified, they fed on the very loose dendritic structure and actually just pulled apart until finally they separated, and so you had these two layers entirely due to an incorrect pouring temperature.

We have found with our larger customers that if once a year or once in two years we get a problem of that kind and tackle it in a more or less thorough manner and then mail them a report with the photographs and other data, it helps our business and seems to establish a feeling of confidence on the part of the user.

I might say the final outcome of this investigation has been that the product made in Canada has been preferred to that made in Europe, because of its obviously greater soundness.

Ductile White Bronze

Now turn to another problem, the question of a white bronze needed for a rather peculiar situation. One of the features was a mirror requiring the Adam period decoration in metal, the metal to be of such a nature that it could be practically pressed down by the thumb to make perfect contact with the contour of the mirror. We were given, to start with, an

alloy containing $5\frac{1}{2}$ per cent copper, 8 per cent aluminum, and 2 per cent tin, the balance zinc, as being that already in use. The difficulty with that alloy is its extreme brittleness, as it was found that when it came to screwing down some of the moldings, by the time the screw had seated firmly the molding had cracked.

We then went to the other extreme in pure lead. We got satisfactory castings in green sand, all the fine contours were easily followed, but for anything but the parts actually lying on the mirror, of course, the lead was too ductile.

We then tried linotype metal, rather feeling that it was too brittle, and it proved so to be. We then mixed linotype metal, which is essentially 12 antimony and 6 tin, with an equal quantity of lead and still had too much antimony. Then we tried 25 per cent tin, the balance lead, a low solder. That, of course, was perfectly all right, we knew the physical qualities would be there, but we doubted if we would get nice castings in sand. However they turned out to be quite satisfactory.

A part of this work was a diagonal grill, of which the outer faces of the diamonds in the grill were polished, leaving every other diamond, which was sunk below, in relief. We finally reached an alloy of 50-50 solder with 2 per cent of antimony, which gave us the necessary rigidity with sufficient bendability—I use that word intentionally, because the bending I find with some of these alloys is not a direct measure of their ductility, it has a relation but it is not a direct one, the two terms are not quite synonymous.

I have mentioned this example because it is a little outside of the ordinary run, and may be of interest to anyone who has occasion to make a white metal alloy of that type in a bronze foundry.

Problem of Casting Buttonhook

Then, we have the very simple proposition of making a buttonhook and shoe horn combined, made of a non-ferrous metal and which has to have the strength or a reasonable approach to the strength of steel. We wanted to make the casting thoroughly sound, and I want to tell you the problems encountered.

First of all, the metal chosen was naturally one of the manganese or aluminum bronzes. In our case we took manganese bronze. At first the mold was made and cast by being gated on the shoe horn end, and tilted and run upwards. Now, I suppose directly I say this many of you will remark, "Well, of course, we knew that was wrong." The effect was that everything ran nicely but the last part of the hook which was more like a cold shot, with a central pipe, and that was the very point we wished to have strengthened.

It was a simple matter, of course, to reverse the operation, cast with the hook end downwards and add a piece of metal on that would enable us to get a perfect run at the end. That was all right so far as the end was concerned, but when we came to make a bending test, we found that

fracture would occur in the center, with that characteristic shrinking effect of manganese bronze, with the yellow spots and yellow porosity.

We then decided that perhaps this central portion was too thick, so we whittled down the pattern and tried to get a more uniform flow. Still pouring from the end and in this position we found that we could not get more than about one-half an arc in the bending. Then we decided that evidently, since the shrinkage was there, the casting had to be fed more, and we gated it from the middle and two inches in the center and succeeded in getting good castings. Placing the casting in a vise we could bring the points of the shoe horn, one over on the other, and the ends would spread apart as good manganese bronze should when released.

Casting Ornamental Bronze Door

Those of you who have to make architectural bronze may be interested in the history of a door about 13 feet high and 3 feet 6 inches broad, and only to be $\frac{1}{4}$ of an inch thick in the casting. The door had large panels in it.

The pattern of this door was built on a board, all panels and moldings being left loose. The pattern consisted of 5 panels 26 inches square, with floral design borders on each side and plain strips between them. The panels were cast in aluminum from a white metal master pattern, which, in its turn, was made from a plaster pattern, and the balance of the floral design was partly in wood with wax design on the wood, and some of the main divisions surrounding the panel were in brass. This gave us brass, wax, wood, and aluminum all in the one pattern.

The first trouble we had was in putting it in the hands of a man who evidently had not been used to the job, and when he drew the pattern he drew most of the sand with it. However, we overcame that trouble.

The flask in which this casting was made was as follows: 15 feet long, 5 feet inside and 14 inches total depth, cope and drag being of equal thickness. The flask was cast iron throughout and the metal of half-inch cross section. Apropos of that, we would advise at least a $\frac{3}{4}$ -inch cross section, but we were very limited in the crane handling capacity where we had to make the casting and we were trying to cut down the weight. We would probably have had a little better result had we made the flask more rigid.

The drag half of the flask had a grill on the bottom and five spacer rods to prevent spring, these rods being one inch in diameter with locknuts inside and outside. The cope half of the box had cast iron bars spaced every seven inches apart. These bars were made to conform to the shape of the door, leaving one inch clearance for the sand. The sand used for facing was new French molding sand milled 24 hours previously in order to allow the moisture to become uniformly distributed.

From the time of the starting of the assembly of the box to the finish of the casting was 12 days, and two molders were employed, with one helper. Two and one-half days of that time was taken in drying the mold

in the oven. The molds were dried in a flat position, the drag half on the bottom and the cope above the drag supported on legs about two feet long, with the intention of avoiding as much as possible the moisture from the lower half disturbing the sand in the upper left half. If we had had the facilities, we would naturally have preferred to have dried the box on edge, as we do with our smaller French sand work, and when we have greater facilities in our new foundry, it will be handled in that way.

The great fear we had was the question of cracking, and every time we handled the box, we had a fear that further cracks would start. We endeavored to locate the cracks along the panels by making separations, and we were rather successful in that the cracks did follow more or less the lines we suggested for them. We couldn't fill in the cracks that occurred in the mold, as probably most of you who have done that work will know why. If you fill anything into the crack, then, as soon as you pour in your metal, the sand expands and forces what was put into the crack outward and leaves, naturally a hole or an indentation in your artistic casting.

The mold was poured from five reservoirs. We are great believers in the reservoir form of pouring. The plugs in the reservoirs were two inches in diameter, with sprues leading to the runners and gates leading from the sprues directly into the center of each panel. We fed in from the back of the casting, the mold being tilted two inches to the foot. The box was five feet, so that gave us about 10 inches angle, and the runner was at the back, the five reservoirs were lined up in equal spaces and the runners went down right across the plate. In addition to that separate runners ran directly into each of the five panels and in that way we managed to get a very satisfactory casting. We arranged to have enough metal left in the reservoirs so the last surface metal, with its skin and dross, did not run in at the last and spoil the casting. The size of the gates was 2 inches by $1\frac{1}{4}$ inches thick leading from the runner and 2 inches by $\frac{1}{4}$ inch leading from the runner into the mold.

Due to the large superficial area of these doors, great precaution was necessary to prevent straining while being poured. To this end, after the cope and drag halves of the mold were closed, perforated steel plates were placed all along the cope surface, with three ordinary rails running the full length of the mold, both cope and drag, and five channel irons were placed at right angles to the rails, with both ends protruding over the sides of the box. These irons were fastened down by long bolts.

The next point of interest probably is the kind of metal used. This door had to match a framework of extruded metal, and ordinarily we should have used a formula of 16 per cent zinc, 3 per cent tin, with possibly up to one-half of one per cent lead and the balance copper. We were rather afraid of this metal on account of the thinness of the casting and the possibility of more dross being in the metal, so we compromised and made it 10 per cent zinc and the balance of the alloy being much the same. The color of that alloy, I might say, worked out quite satisfactorily.

The metal was melted partly in an electric furnace of the arc type and partly in crucible furnaces. This work happened to have been done in one of our foundries in which we had to use the crucible type of furnace in place of all electric. We took the metal out of the furnaces at 2350 degrees Fahr., tested by the pyrometer. We believe that we poured it at about 2150, because, obviously, as you fill all the reservoirs, you have to wait until they are all full, and then you must pull all your plugs simultaneously and you are not in a position to be quite sure of the final temperature. I mean that, as a practical thing, by this time you are not wandering around with a pyrometer in your hand. If you have patience to take the temperature of the metal coming out of the furnace, when the actual pouring takes place you feel like leaving the pyrometer and watching the process.

The result of this procedure was a casting which had no obvious flaws on the whole of the surface. We made the second casting just before I came out here. The skin of the casting was continuous, there were, I should say, about six cracks, which pretty closely followed the panels, and the chasing required was very small and the net result was what I think one would really call a good casting.

These illustrations are just a few points of foundry problems. When I told my superintendent of the subject upon which I was to speak, he wanted to know how many days I was going to talk, imagining how long it would take to tell all the problems and troubles that we have in our own company. We realize that we have troubles every day and all of them do not come out as successfully as some of the ones which I have enumerated. We have trouble with lead poisoning, and ventilation, but I don't want to take up the time of the meeting with such subjects as that.

DISCUSSION

C. H. ERICKSON: At what temperature was your oven when baking or drying that mold?

H. J. ROAST: I cannot give you an exact figure, for while in our other foundries we have fairly complete control we do not have it here. It is an old type of coke oven. It is a rather unusual size for the foundry in question. We had to put it into an oven which had no form of control. Had I had such control, I should have dried this mold at between 400 and 450 degrees Fahr., and I imagine it was somewhere near there, but I am sorry I can't be definite.

CHAIRMAN G. H. CLAMER: I was particularly interested in Mr. Roast's description of the segregation of phosphorus. We have had some experience in noting the segregation of phosphorus and tin in heating up castings. I remember one case particularly where we had a phosphor-bronze locomotive bearing. That bearing became heated in service to such a degree that a little nodule of metal, probably an inch or an inch and one-half long, ran up into one of the oil holes. That little nodule of metal, upon analysis, was found to contain 22 per cent of tin, about 3 per cent of

phosphorus, several per cent of lead and the balance copper, whereas the original casting was of the 80, 10 and 10 type with only 0.7 per cent phosphorus, showing a segregation of the eutectic, and under the heat and pressure it had been forced up into this oil hole.

That same thing, of course, happens if you pour your casting too hot, and it frequently happens that that kind of a constituent forms around the outer surface of the casting and, of course, is hard to machine and eats into the sand, etc.

I remember also a case of the development of that dendritic structure that he referred to. We were making some grab handles for trolley cars of the type used in the old days and this particular mixture was one of about 12.5 per cent zinc and the balance copper. That alloy is more prone to the development of that dendritic structure than the alloy that Mr. Roast referred to. One of these grab handles broke and we very nearly had a lawsuit on our hands when it was broken and it was found that it was of that complete dendritic structure.

W. M. MARR: Mr. Roast, did you add any deoxidizer to your ladles when casting the door?

H. J. ROAST: No deoxidizer other than the fact that we added the correcting amount of zinc. First of all, the metal was ingoted, then we added 1.25 per cent of zinc just before pouring. That is a method which I have found to give satisfactory results. There is quite a violent action with the zinc. We did not add any phosphorus in this instance at all. We started off by taking pure metal to make the ingot and we took all the precautions we could in regard to covering it with charcoal. Generally speaking, we use phosphorus in other alloys.

C. H. ERICKSON: On that tin sweating, I believe there is a large amount of sweating on castings that is called tin sweating and which we have found was lead. We keep our lead down quite low and keep our tin up about five points and we don't find any of that in castings.

H. J. ROAST: In this metal we had no lead except that which we picked up in melting from the electric furnace. We probably had about 0.2 per cent of lead in it.

CHAIRMAN G. H. CLAMER: Mr. Roast, have you found very much difference in color in going from the 16 to the 10 per cent of zinc? Did your alloy still match the extruded metal satisfactorily?

H. J. ROAST: It did match it satisfactorily. There was very little difference in the color between the two alloys. In fact, they matched so well that we rather think we are going to turn to the 10 per cent zinc in place of the 16. I might say that before we take any job of that kind on, we cast a test panel which is about a square foot in size with a lot of heavy relief in it and we take that for all work of that nature, and we test the alloy that we are making for its capacity for filling all the fine detail of the mold. If necessary the same test panel will be used in connection with the acid cleaning of the door in order to see how the metal reacts and what form of acid dip is the best for that particular job.

We find that control panels for artistic work and control simple castings for other work saves us a great deal of trouble and are oftentimes quicker than having analyses and other tests made.

W. F. GRAHAM: Mr. Roast suggested that the intercrystalline or interdendritic fissure was caused by high temperature, and Mr. Clamer mentioned the effect of phosphorus. I wonder if Mr. Roast would care to differentiate between the effect of temperature and the effect of melting condition or phosphorus content as the cause of the inverse segregation or interdendritic fissure.

H. J. ROAST: I agree with what I think you said, that is, that the two are tied up together. If you don't have the phosphorus, if you take that same alloy minus the phosphorus, you do not have anything like the same size of dendritic structure under fixed conditions. You have, in addition, the possibility of the separation of the eutectic itself, which is making the joints of the crystals the weakest part, and I would say that it is due essentially to the presence of the phosphorus, which does affect the size of the dendrites and which does weaken the bond between the two.

W. F. GRAHAM: I may say that that explanation coincides with our feeling in the matter, too, as regards the effect of phosphorus with temperature.

CHAIRMAN G. H. CLAMER: I am also in a position to corroborate that point, having noted upon occasions in heating up large phosphor-bronze castings in order to break them the dendritic structure is developed in the heating operation and the fracture is entirely dendritic when the castings are broken.

DISCUSSION—ELECTRIC ARC FURNACES

The next paper presented was on ELECTRIC ARC FURNACES IN GENERAL JOBBING BRASS FOUNDRY, by J. B. Meier of the F. & H. Foundry Company of Newark, N. J.

MR. BURLEY: Was the loss of Table 1 a metal loss or a melting loss; is it loss within the furnace or the total loss of the foundry due to spilling and cleanings and things like that.

J. B. MEIER: It was the total metal loss, not in oxidation loss or anything of that sort. We have no way in our foundry with the present personnel for determining what the oxidation loss is.

H. J. ROAST: As a user of electric furnaces, I would like to say that there may be some here who are in doubt as to whether electric melting is good. There are several types of good furnaces. We have melted in our furnaces with the present lining three and one-half million pounds of metal coming out at 2,200 to 2,300 degrees Fahr., containing 20 per cent of lead as a maximum and 14 per cent as a minimum, and we naturally feel that with one lining that is not so bad. Based on our total consumption last month the rate was $1\frac{1}{4}$ cents per kilowatt hour, but perhaps we are more favorably placed in Canada than you are here.

In regard to the patching, we believe that you cannot do too much patching. Continuous patching is a safeguard and represents the length of life that you will get out of your lining.

In regard to carbons which have become broken, not being of any use, we take them and bore a very rough thread in them, put them on a wooden handle and use them for work on aluminum bronze, in which we are anxious for certain specifications to keep out the iron. In other specifications, of course, we like the iron in.

Taking it all around, for our particular type of work we feel that we get excellent satisfaction from our electric furnace.

H. M. ST. JOHN: Since we operate a rather large foundry, exclusively electric, of this type of furnace, these cost figures are naturally interesting. At first glance, they look pretty high. There are probably a good many foundries operating at cost figures not much more than half those shown by Mr. Meier. On the other hand, when we look at the figures in detail, I think Mr. Meier is rather to be congratulated for having his costs so low. In the first place, he has a rate of practically 2.6 cents per kilowatt hour, which is certainly pretty high. His five-minute demand helps to explain that. Just to show the difference, in Detroit we have a monthly demand based on the average of the highest three hours in any day and that is automatically revised month to month, so our demand one month doesn't apply to the demand in the following month. That, naturally, is quite a help. Our rate runs about 1.6 to 1.7 cents.

On the fuel oil for ladles, the cost is probably about twice what it ought to be, but I think Mr. Meier has explained that.

As to Mr. Meier's metal loss, I think he has mentioned the fact that quite a bit of the material added contains a good deal of none-metallic, which naturally doesn't show up as good metal and is part of his 2.4 per cent loss.

The difficulty with labor is probably quite a serious factor in increasing the cost. In other words, in order to operate furnaces of this type economically, it is necessary to do certain operations, such as charging and pouring, with almost military precision. The man needs to be exactly where he is needed at exactly the right time. There should be no delays when the metal is ready to pour; the pouring gang must be there. When the furnace is ready to be charged, the man must be there to charge the furnace. With 800-pound furnaces we regularly pour and charge in about four minutes per charge, and it makes a world of difference in the efficiency and ultimately in the cost not to do this on schedule.

I don't know just how the bonus system works out, we don't use it, but we do find it pays to use white operators and we pay them on the average of about 85 cents an hour, with no bonus. It is possible, at least in our territory, at that price to get operators who are thoroughly dependable, and so many of these cost items depend upon the reliability of the operator that a few cents added to his hourly wage can easily be saved in electric power, electrodes, and some of the other items mentioned.

J. H. CHEETHAM: I notice in the sketch (Fig. 1) the author has crucible and ladle heaters. I was wondering just about what size crucible he has and the ladle capacity, and also whether in the use of the two different kinds he has any preference for a certain type of metal in the use of crucible or in the ladle. Also, we have tried the crucible in a ladle with the broken fire-brick that he describes on page 320 and we find that in pouring it the outside broken fire-brick will crumble and go into the mold and cause dirty castings. I wanted to know if he had that trouble or not.

J. B. MEIER: As far as the first part of your question is concerned, we do not use anything but the ladle heaters at present. We are using the crucibles in the ladles as shown on that sketch.

As far as the broken fire-brick is concerned, we have not encountered any of the trouble that you have mentioned. Of course, it is imperative that the fire-brick be forced in there properly, and then we also cement over the top about an inch, a half inch at least, with a patching material, which tends to hold that in a homogeneous mass. We have not had any of the trouble that you speak of, as a matter of fact.

WITOLD KOSICKI: As long as there are so many men running electric furnaces here, I would like to find out if anybody has made a comparison between the running of an electric furnace and the crucible furnace. Can anyone give a little idea that might help people who want to install the electric furnace and are figuring on the cost? What will be the cost if we are running six or eight crucible furnaces and want to change to the electric furnace? How does the cost figure, roughly? Of course, I realize that that will vary considerably in different localities, the power cost will be one price in New York and another price in Detroit, but, roughly speaking, what will be the ratio of the cost between crucible melting and electric furnace melting?

H. M. ST. JOHN: We used crucible furnaces exclusively, natural draft coke, before we put in the electrics. I don't think it would be safe to use our comparison in any other plant without making the necessary qualifications, but in our particular case the saving was about one-third of the over-all cost for the electric system as compared with crucibles. That includes the difference in metal loss, of course.

W. M. MARR: I think Mr. St. John's statement bears out our experience very well there. The net gain, of course, in the electric melting comes in the savings of the metal. There it would depend on your records and how thorough they are and how good they are and how dependable they are as to just what kind of a figure you are going to get out. The operating cost, as such, I would say the electric, of course, is higher, but when you consider melting loss, it is in favor of the electric furnace.

H. J. ROAST: I am sorry I can't give you the actual figures because I don't remember them, but I am quite convinced that there is a saving in the electric furnace over and above the saving of the metal. I would like to ask Mr. St. John if the crucible furnaces were coke, oil or gas fired?

H. M. ST. JOHN: Natural draft coke.

H. J. ROAST: Is the question of the expense of taking the coke and ashes, etc., out and in considered?

H. M. ST. JOHN: That was all included.

H. J. ROAST: Our experience has been that undoubtedly you can save money on the actual operation as well as on the metal loss; there is also a saving on the results of the castings produced with the same type of mold.

CHAIRMAN G. H. CLAMER: Of course, the one great factor in operating electric furnaces is to really operate them, that is, to get somewhere near their capacity. If you do that, then I think you can beat the crucible.

H. J. ROAST: I think you have to remember that fuel in Canada costs us more than fuel here.

E. F. HESS: While I haven't actually secured the figures on our coke consumption myself, I have taken data as they were given to me, and I find we have reduced our melting cost considerably with the electric furnaces. In fact, we have two different types of furnaces. Some years ago we had a type of furnace in which the linings seemed to increase our cost quite a bit, and since that time we have purchased a new type of electric furnace and have reduced the cost considerably. I think we had the natural draft coke furnace to begin with and the cost figures now are practically half of what they used to be. Of course, the metal loss was quite a bit when using coke furnaces caused by metal dropping down into the pits.

J. H. SCOTT: Back in 1919, we changed from crucibles to, I suppose, the second or third furnace of one manufacturer. We found that we could make more money in manufacturing ingots and melting scrap, including all kinds of heavy and light scrap. The cost was much less than one-third as compared to Mr. St. John. We then started to cast brass billets, pouring direct from the furnaces into the molds. We had three types of electric furnaces. We found that there was considerable saving in all types of electric furnaces. In fact, in any plant that I have been connected with, I have never seen any place where the crucible could compare with the electric, as to cast, better working conditions, safety to men and more balanced metal temperature.

W. F. GRAHAM: I have no comment to add regarding the author's figures. Mr. St. John and others made a very good analysis of them, but I do have a suggestion to make that a standard method of arriving at melting costs be worked up by our Non-Ferrous Division, much the same as engine testing and boiler testing have been covered by other societies. In attempting to make these comparisons, no two shops use the same basic figures and discussion of this kind only adds to a considerable controversy that has already existed, without really pinning the matter down. Not only that, but, going further into the matter, as the art advances these comparisons will naturally further the economic use of the best furnaces, whatever they may be, when the results are compared in open forum.

CHAIRMAN G. H. CLAMER: I think that is a very good suggestion. Particularly in talking costs, it is pretty hard for everybody to talk the

same language unless you have some form or standard practice instruction to go on. The real fact is that in comparing crucible melting or any other type of melting with another type, you have to have exactly the same conditions for comparison. You can't talk of costs in one shop as compared with another or one metal with another. Even from heat to heat it varies, so you really have to get very standardized factors to start with.

A MEMBER: Regarding the bonus system that you spoke of. Was that in operation when you had the first transformer?

J. B. MEIER: We started out originally with the bonus system based on what we called a percentage of efficiency. That is, we assumed the manufacturer's guarantee as standard and we paid the operator on that basis. We had quite an elaborate scheme for paying him, based on how near he came to this standard. That entailed quite a little bookkeeping and we tried to simplify the matter and base it on the number of heats, and we were doing that previous to the installation of the last transformer. He has gained slightly by the fact that this transformer is a little faster than the other one, and that has reacted to his advantage slightly.

F. D. CROUCHLEY: I am connected with the Public Service of New Jersey. It seems that many of you gentlemen want to get at this question of costs as many of you don't know what your costs are. You might think that the power company is not interested in your particular line, but it is, and you should know the power salesman who is connected with the company that supplies you. We take a great deal of interest in trying to know something about your industry. Of course, we have to deal with every industry in our city and we try to help you get the costs down.

You speak about your demand load coming on. We have a demand charge and an energy charge. Now, if the small customer and also the larger customer who runs over \$1,000 a month (that may seem a lot to some men here, but that is not for melting, it may be just for your grinding and conveying and other power load required) would get hold of your power man and figure out the wholesale rate, the parts of the rate that will tell you just what your melting costs are, I am sure you will be more interested in it from just the rate and your entire bill. If you will look at your entire rate, it may figure out 2.5 cents, and that is the over-all rate for your entire foundry. To figure your melting cost, it might mean putting up sub-meters around your place to figure out what your other load is, but you get down to the cost of it, and the power man might make some suggestions to you and work right along with the manufacturer of the furnace. We like to go along with you because we live with the customers; the furnace man sells the furnace, he is here today and gone tomorrow, but we come around every month and collect that bill, and we like to see that you get a proper rate. We are obligated to give you the best rate, every utility is, and we feel that when you are calling in your furnace manufacturer, you ought also to get in touch with your power company and see if they haven't some suggestions to offer for your cycle of operation.

MR. HEALY: When I was with Gardner at Quincy, Illinois, we installed an electric furnace. Of course, this old question of demand came up, but I was successful in getting away from the demand on that furnace provided we didn't use juice after a certain time in the afternoon, and it was entirely possible for us to operate that way and they waived the demand, so we didn't have to pay any demand at all on that electric furnace.

I might also add that our iron foundry floor was operated exclusive of the demand.

CHAIRMAN G. H. CLAMER: As I understand it, conditions have now changed and the peak really comes in the daytime, doesn't it, instead of night, as formerly, in most sections where they use power units?

F. D. CROUCHLEY: In different cities it comes at different times of the day. In New Jersey we don't have a peak. In New York and Brooklyn they have a peak in November, December, January and February from 4:00 P. M. until 9:00 P. M. You may be able to stagger your load. You may have a machine load of 400 or 500 horsepower, and, billed on a demand basis, establishing a demand, say, of 300 horsepower. Now, if your electric furnace comes along with 100, it would be figured on the last step of the demand charge. If your plant is large enough and you run at night, there is no additional charge for this demand.

The last gentleman said he has no demand charge. Well, you can figure all your energy, then, at the last step, three cents, one cent, or eight-tenths of a cent, depending on how much you use and how you use it and what your demands are. Now, Mr. Meier's foundry pays roughly \$1,000 a month, he has a small foundry, and that cost is all for melting. You men of other foundries with a lot of machine work, your electric bill is five hundred or six hundred dollars a month anyway. That is a small bill. You may be able to stagger your load or figure your demand charge at the last section of the demand rate.

I might say something about the way our demand is established. We have a five-minute interval on our demand meter. Every five minutes that needle reaches a maximum. We take the maximum for the day. Let us assume, we will say, that you establish a 200 horsepower demand, 100 horsepower on each furnace. When both are on, they establish a 200 horsepower demand. We will say there are 25 working days in the month. If you run 24 days with only one furnace on the line, your demand then is 100 horsepower. If, on the last day of the month, you run two of them, you establish 200 horsepower demand. Averaging up the days, 24 days at 100 would be 2,400 and one day at 200 would be 2,600 and we divide the 2,600 by 25, so you would not be billed on a total of 200. That just happens to be the way our demand is established. Our demand changes every month. With some companies their demand will be established for a month and it will hold good for 11 consecutive months.

Now, we believe in New Jersey that we have a very fine rate. Of course, we are not talking about hydro power, but we have a good rate in New Jersey.

Malleable Iron

Three papers were presented before the session on Malleable Iron. The first presented was on "Practical Aspects of White Fracture Malleable," by D. P. Forbes, and will be found beginning on page 405. The second paper was "Controlling the Atmosphere in Malleable Annealing Ovens," by W. F. Graham, and will be found beginning on page 295, and the third, "Shrinkage of White Cast Iron" by H. A. Schwartz, will be found beginning on page 205.

DISCUSSION—PRACTICAL ASPECTS OF WHITE FRACTURE MALLEABLE

WRITTEN DISCUSSION—SUBMITTED BY L. H. MARSHALL

It is becoming more and more the rule for the consumer to test out his purchases before putting them into use. A very admirable practice that serves as an effective preventative of subsequent grief. To the producer of malleable iron castings, however, it means a more frequent occurrence of the old conundrum—when is malleable iron not malleable? The general answer is—when it has a white fracture.

Due perhaps to the superficial resemblance of the white fracture discussed in this paper to that of hard iron, combined carbon has at times been presented as the cause of the trouble. That premise was disposed of by W. R. Bean in his paper before the American Institute of Mining and Metallurgical Engineers in 1923. He showed that silicon and particularly phosphorus were effective in producing the white fracture. The important role played by heat treatment and thermal effects was not stressed in his paper but has since been demonstrated.

The matter of assigning a definite cause for the results observed is still a difficult one. As the author points out, there is need of demonstration that some element or combination will develop the characteristics exhibited by white fracture malleable iron. Although silicon and phosphorus seem clearly connected with this phenomenon, there is no record that they produce such results in any other ferrous alloy.

It is known, however, that pure iron containing nitrogen exhibits thermal effects around 800 degrees Fahr. Iron nitride is also capable of causing dispersion hardening at about room temperature. This nitride tends to go into solution in iron at 1200 degrees Fahr. These facts have all been demonstrated on quite pure materials and have to do with similar temperature ranges to those under discussion for malleable iron. There is the suspicion, therefore, that there might be some connection between the two. The reference in this paper to the faulty behavior of abnormal heats of malleable iron perhaps adds weight to this supposition,

as nitrogen may be picked up in the melting process. The presence of silicon in malleable iron would probably aid in the tendency to add nitrogen.

In any case a study of relatively pure iron-silicon-phosphorus alloys, with or without the presence of nitrogen, would be very likely to throw further light on this vexing question. It is most certainly a research problem and the malleable industry might well cooperate with the Bureau of Standards or some similar agency to attempt its solution.

WRITTEN DISCUSSION—SUBMITTED BY H. A. SCHWARTZ*

The writer would offer a few words of comment and confirmation with respect to Mr. Forbes' paper.

The author has clearly brought out the identity of the fault which he describes and the fault occasioned when malleable iron is embrittled during the galvanizing operation. The relation between galvanizing embrittlement and heat treatment was studied by Leslie Marshall at the Bureau of Standards and described in "Embrittlement of Malleable Cast Iron Resulting from Heat Treatment," *Technologic Papers of the Bureau of Standards*, No. 245, November 26, 1923. W. R. Bean, "Deterioration of Malleable in the Hot-dip Galvanizing Process," *American Institute of Mining and Metallurgical Engineers*, Vol. LXIX, 1923, page 895, has discussed the effect of silicon and phosphorus on the embrittlement of malleable by galvanizing. Mr. Forbes now shows us publicly that the fault which can be produced in galvanizing can also be produced under equivalent conditions during the supposedly normal heat treatment of malleable and it is well that this identity should be generally comprehended.

His tentative explanation with respect to the effect of phosphorus bearing films is of very considerable theoretical interest. In this connection the following reflections may be pertinent. Neither silicon nor phosphorus, the two elements which Mr. Forbes as well as Mr. Bean regard as of major importance, will migrate in iron with any very great rapidity. It is likely, therefore, that after annealing they will be found largely in the same positions which they occupied in the original hard iron. If, therefore, either phosphorus or silicon films determine the course of inter-crystalline fracture, then the crystal boundaries of the ferrite in malleable must in some measure coincide with the position of the phosphorus or silicon in the hard iron. Whether or not this is true, the writer does not now know, although Mr. Forbes' paper has furnished an impetus for an investigation in this direction.

It is not generally known, perhaps, that malleable iron if etched with a boiling solution of sodium picrate so concentrated that crystals form upon its surface will show a dendritic pattern which though not sharply marked is qualitatively similar to the structure of white cast iron. No means of experimentation is known to the writer for proving whether

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FIG. 1—MALLEABLE IRON EMBRITTLED TO PRODUCE WHITE FRACTURE BY QUENCHING FROM 850° FAHR.

this pattern is actually identical with the pre-existing hard iron pattern or one of the same type. He has thought in the past, however, that it represents the dendritic segregation of some other element, probably silicon, although it might equally as well have been phosphorus occasioned by the original dendritic segregation of carbon and, therefore, preserving a pattern corresponding to the original carbon concentration.

Mr. Forbes' investigation now suggests an attempt to correlate these etch patterns with the type of fracture to which he alludes.

The accompanying micrograph of Fig. 1 represents a piece of malleable embrittled to produce white fracture by quenching from the neighborhood of 850 degrees Fahr. The broken surface was plated with copper and a section prepared through the malleable iron plus the copper plating to show the path of rupture. The copper and specimen were then etched as indicated, the etching medium strongly attacking the electro deposited copper at the top of the picture. The dendritic pattern left by the combination of etching and heat treating is plainly visible superimposed on the usual malleable iron microstructure.

The writer has not, however, been able to observe any preference on the part of the path of rupture to pass in any particular direction with regard to this etch pattern, in other words, at the boundary of the iron which represents the path of fracture the metal does not tint either more or less or any more consistently of one tint than anywhere else. The results are thus entirely negative.

It may be relevant here to say that the change produced by the "Flecto treatment" or the change produced by warming a metal to 200 degrees before breaking can hardly be the formation or destruction of films but may only be the change of properties in the film as the result of temperature or heat treatment. This conclusion rests, not only upon considerations of plausibility, but is supported by the fact that heat treatments which change the character of fracture from intergranular to transcrystalline and back have been shown in the writer's laboratory by direct experiment to be unaccompanied by changes either in electrical resistance or magnetic permeability even when the tests were made on the same sample before and after heat treatment. It would seem that these two properties should be very strongly affected by the presence of films and the experiments some years ago were, therefore, carried out in the hope of proving or disproving whether a film existed in the case of white fractured iron which did not exist in the case of black fractured iron. The problem is now being attacked on the basis of X-ray crystallography and in the event of positive results may form a subject of publication covering the electric measurements in detail. So far it has not been thought worth while to take space for the actual figures in view of the negative character of the conclusion.

MR. KELLY: We have made a lot of white fracture iron and as Mr. Schwartz says, that metal is weakened by the phosphide or any other oxide that may be in the metal when the white fracture is produced.

After you reanneal that white casting it is all right, abnormally good, very strong. How do you account for that?

D. P. FORBES: In Mr. Marshall's written discussion he makes the statement that there does not seem to be any other material than malleable iron which shows this same white fracture tendency. I talked to Dr. Anson Hayes about this at one time, and he said that in a certain high silicon production of the American Rolling Mills, which was used, I think, for laminated magnet cores, they found this same condition to exist. I do not know any of the details of it at all or what the percentage of phosphorus would be, but I believe Dr. Hayes said that it would yield to the same treatment of the Flecto process and would be very ductile.

Mr. Schwartz's film theory is a very interesting one, and one which I had never considered at all. My own opinion of the thing when it is finally solved is that they will find that this film, and it must be a film or something similar, is an alloy which has certain recrystallization properties. It might be that quenching from 1200 degrees would supercool that film so that it would not recrystallize at 850 degrees, which seems to be the critical point, and that subsequent heating to 850 degrees for a period of time would cause that film to go back into some other form, which would display crystalline properties. I have no idea what the film might consist of.

Mr. Kelly reports that the reannealed castings were O. K. We have found that condition to work out sometimes and sometimes it does not. We have reannealed whole ovens full of material which was largely white fracture, and we would find that we would still have a large quantity of white fracture material, although we'd get some improvement. The success Mr. Kelly has had might be explained by this phosphorus theory; that in reannealing he had a longer time at the critical point for this phosphorus film to be reabsorbed in the ferrite.

DISCUSSION—CONTROLLING THE ATMOSPHERE IN MALLEABLE ANNEALING OVENS

W. F. GRAHAM: I want to call your attention to the fact that the gas analysis represents the composition of the gases in the furnace chamber and not in the annealing pot.

W. R. BEAN: The subject of this paper is one of very special interest to me, personally, and to our company. The purpose of the experiment is primarily to improve the quality of the product by a reduction of oxidation of the castings. At the present time, and for some months past, we have been carrying on experiments calculated to produce, I believe, the same result or a similar result by more perfect control of combustion.

Studies which we have made indicate that the amount of fuel necessary to hold an oven at temperature after the mass has been brought up is in the proportion of something like eight or ten to one. In other

words, if an oven requires the firing of 200 pounds of coal per hour to bring it to temperature, the amount required to hold at that temperature will be something like 20 or 25 pounds of coal per hour.

That difference is such that it is not practicable to produce the condition through a single burner, and that is one of the things which Mr. Graham encountered in experiments which he made. When reducing the volume of air passing into the oven with the fuel to a point commensurate with the small amount of coal that is actually required to hold the temperature, a high local temperature is the natural result, and to overcome that handicap in our most recent installations we are putting in two burners, one burner of a size to fire the amount of coal necessary to bring the mass to temperature, the other of a size to carry the amount of coal and air required to hold.

The question of maintaining an approximately uniform temperature throughout the length of an oven is one of projection of flame. With the burner used in bringing up the temperature, we carry a condition to throw the flame to the front of the oven and have a variation of not more than about 100 degrees between the two points. We then can duplicate that condition by throwing into use the smaller burner and reducing both coal and air to the amounts necessary to hold. We have run as low as 11 pounds of coal an hour in holding an annealing oven at temperature. The result there is an approximately uniform atmosphere throughout the period, a greatly reduced coal consumption for the annealing process running in some very recent trials down to about 400 pounds of coal per ton of castings annealed, a ratio of approximately five to one.

The figures are not available as to the change of oxidation, but the tests made so far indicate about a 40 per cent increase in pot life as a result of a better flame condition and flame control in the oven.

The condition which Mr. Graham may have obtained there is the amount of oxidation of the carbon from the exterior portion of the casting. I cannot help but tie the result here definitely to machinability of malleable castings. Machinability is, I believe, one of the most vital points which the malleable industry faces today in the demand of the automobile industry for castings which can be machined at a high rate of speed without injury to tools and equipment from toughness.

Most of our complaints from the users, and particularly the machiners of malleable castings, come not from hard castings but from tough castings. As an actual fact, they may not always differentiate, but the condition is there, and by reducing the amount of decarborization from the surface a vastly better material must result. Whether the method which has been adopted or is being experimented with by the Ohio Brass Company or a proper control of the flame by control of the volumes of air and coal will prove to be the one best calculated to produce the maximum efficiency in the overall result, it is a little early to determine.

The most recent installation of equipment for annealing has an automatic control for maintaining a uniform temperature throughout the holding period, by connecting to the starting device a pyrometer so arranged that the temperature can be held within a range of twenty degrees approximately. The dropping of the temperature below a certain predetermined point will start the equipment, and as soon as the high point is reached, the firing equipment will be automatically shut off.

One thing that we have not definitely tied to that is damper control, which, however, can be very readily applied. On the oven, however, we find that there is enough leakage around the damper when it is closed. I think 99 per cent of the annealing ovens in use in the malleable industry today have enough leakage, so that we have not yet found it necessary to go to damper control. It is entirely practicable, however, and devices are available as standard equipment for controlling dampers, so that the damper of an oven may be opened and closed at the same time that the supply of fuel and air is put on or taken off.

DISCUSSION—SHRINKAGE IN MALLEABLE CAST IRON

D. B. SPENCER: As I understand it, you do not draw a line between the definition of shrinkage and contraction. The experiments as you have outlined them, have more to do with contraction.

H. A. SCHWARTZ: To me, contraction means the thing the pattern maker corrects. There is a discussion of that to the extent that all white irons are alike. Shrinkage means to me the decrease in volume, not of the casting as represented by its exterior dimensions, but of those dimensions less voids that are in the interior of the casting.

D. B. SPENCER: Shrinkage, of course, is determined largely by the rate at which the metal sets and the speed at which the gate feeds.

H. A. SCHWARTZ: In so far as that affects the temperature at which you are pouring, I should think that would be so.

J. T. MACKENZIE: I have tried Mr. Schwartz' sphere on everything from white iron to very soft gray iron. We had the trouble that the surface would not be strong enough to support the shrinkage and that the top of the casting looked like a cocoanut, two eyes dimpled in, and in some cases the pipe ran a good ways down into the metal. That gate is a little bit small in case you are trying to pour very wild metals, where the shrinkage is at its worst, near the freezing point, and it is also very troublesome in the case of a hypereutectic alloy where you begin to have graphite freezing out.

The Bureau of Standards in its investigation for the A. F. A. is attacking the problem of trying to get all of the shrinkage as an exterior cavity in the top of the casting. I myself have used with little better success than the ball, a step casting, round, with a diameter of four inches for four inches of its length, then two inches in diameter for four inches, and so on down, so you get a tremendous draw from the bottom of the mold, and there is apparently no subcutaneous cavity. Simply by

filling the top of the casting with water, measuring the volume, and knowing the weight of the casting, you can calculate the shrinkage, and in comparative tests we have found that this step casting, stepped as a hot top ingot, gives us nearly twice the shrinkage that the Schwartz sphere does.

Another trouble is that with the high shrinkage alloys it is very hard to get sound metal to make your original density determination from, and you have to grind off the surface or else the sand will hold bubbles of air on it. Mr. Schwartz mentioned doing that by evacuating so as to get rid of that condition, but it is astonishing how many small cavities you can find in those gates with the high shrinkage alloy.

H. A. SCHWARTZ: In connection with the forms of test bodies employed we must not forget that a body whose shell freezes under considerable ferrostatic pressure will be larger in overall bulk than otherwise due to plastic stretch of shell. Such an object may show abnormally high shrink.

H. W. GILLET: How closely did your duplicate determinations agree on the same metal from the same furnace and same heat?

H. A. SCHWARTZ: In Table 7, there are four determinations on each of seven alloys. That is about as the things would run.

H. W. GILLET: There is a variation in one case from 1.7 to 2.8—I should think that would mean that you would have to plot one point for the curve as circles to show the deviation of duplicate determinations.

H. A. SCHWARTZ: We attempted to calculate the probable error of the determination as compared with the probable error of determinations on various materials and the results of Table 7 were among the early data. They were on laboratory melts. The results are pretty largely variable if you take only a single observation. We originally hoped that a single ball on a melt would do. We found it did not. We have had the dimpling effect on the surface and I can imagine that in gray iron it would possibly be still more serious since the metal is more fluid. We sometimes overcome this error by plastering paraffin into the dimple and weighing the amount of paraffin that we put on. When we figured it out that way, we found it was not such a very large amount in relation to the total per cent of shrinkage that we got.

We once had the idea that we would make a test specimen six inches in diameter and an inch high, hoping that the entire surface would collapse, the thing would be concave, and that we could measure by pouring in alcohol or by micrometer measurements of the depression and get the results that way. General work with the two methods suggested that we would get further with the spheres than we would otherwise. The gates themselves by which the balls were fed from the runner underneath, I think were always very sound. We quit worrying about getting a dense specimen from the gate to do the basis density determination on, when we found that it was easier to take the analysis and calculate the density.

We were very precise with the material which was the basis of our

density work and after that we did not worry whether the runner underneath was sound or not. When we determined densities directly, we used pieces from the toes; that is, the furthestest point. It is true that the surface usually shows air bubbles. We were rather of the opinion that we got the air displaced out of those small depressions, but we were not quite sure whether those air bubbles should be part of the shrinkage of the metal or not. We were not sure whether they were liberations of gas which occupied volume in the metal or whether they were not part of the original volume of the metal, so there the interpretation grows difficult.

Replying further to Dr. Gillett's point, I don't think the method can have any claim to great precision. It is intended as something that you can do to heats that you are making in a foundry. I believe that if we were to determine the change of density during melting in a material submerged in a liquid by the Archimedian method, we would get better precision, but we could not get such results in connection with commercial melting practice, so that, although we played with the possibilities of those methods, we did not acquire any practical knowledge as the result of them.

It may be well to note that our data are expressed in percentage of voids, a small number obtained by differences from two large numbers. Had we these instead as a percentage of metal, the results, though neither more nor less accurate than before, would have looked more impressive for the variations would have been about 1 in 97 instead of 1 in 2.5. On the other hand, it is possible that the unknown variables are due to the method rather than the metal.

W. F. GRAHAM: Mr. MacKenzie presented some views of this from the gray iron side. I want to switch over to another division, non-ferrous side, and say that about a year ago we attempted to study this particular kind of shrinkage more or less along the same methods of attack, and did not get very far, running into many of the difficulties that Mr. MacKenzie has mentioned when handling brasses of different compositions. I have not in mind the exact details of the difficulties the workers ran into, but possibly this paper will serve as an inspiration for a further attack on this problem in both our brass and malleable foundry operations.

D. P. FORBES: I would like to ask Mr. Schwartz if in the course of any of his investigations, he has determined the freezing behavior of white iron for a different carbon and silicon analysis, and if he has done so, whether he has found that iron produced, for example, in an air furnace would for the same identical analysis have identical freezing points with iron produced in an electric furnace?

H. A. SCHWARTZ: We have not actually done that.

D. P. FORBES: I brought that up because it might have a bearing upon the rate of shrinkage. That is, one metal might start to solidify and the surface become rigid at a higher temperature than another metal

of the same carbon and silicon analysis, assuming that there is some other factor that might have a bearing.

R. E. BRYANT: We make pipe unions and the parts are subjected to air test under water. We have found a directly traceable relationship between our air test reports on finished castings and the evidence, no matter how small to the naked eye, of shrinkage in the white iron fractures, and it is our practice to break a number of samples from each pattern, each heat, to check up for the shrinkage. A few years ago, in going over that data which had accumulated over a considerable period of time, I evolved a relationship which seemed to be tied up with the incidence of shrinkage which I was interested to see confirmed by a much more painstaking investigation by Mr. Schwartz. We developed that same relationship of three times the value of silicon to one of carbon, and developed a formula which we have used sometimes in connection with that work in comparing our actual analysis in any heat with a definite standard. We found that the incidence of shrinkage could be related to the variation in carbon plus three times the variation in silicon in the same direction.

C. M. SAEGER, JR.: I would like to ask Mr. Schwartz if he has ever taken two molds, connected them with a runner box and then poured the two molds at the same time, and whether any difference was found between the two test molds? Is there a great variation between shrinkage values so obtained?

H. A. SCHWARTZ: We have not done just that thing; the using of four spheres on one runner was our idea of doing that and Table 7 is the variation of the four spheres.

H. A. SCHWARTZ: Since the paper was completed there has been opportunity to check the observed data on shrinkage as expressed in the formula in the section (page 233) on "Concluding Observations" against the shrinkage calculated from the density data.

The data of Gorton and Austin are the only ones concerning themselves with three variables, Honda and Endo having worked with constant carbon. Combining their equation for the density of liquid iron with their graph for the coefficient of expansion as a function of silicon we may say that at temperature T ,

$$\begin{aligned} \rho_T &= 7.16 - 0.10 \text{ Si} - 0.07 \text{ C} - (.0035 - .00165 \text{ Si}) (T - 1450) \\ &= 12.235 - 2.42 \text{ Si} - 0.07 \text{ C} - .0035 T + .0016 \text{ Si } T \end{aligned}$$

From the data of Guiler on the density of white cast iron at room temperature and the linear shrinkage of white cast iron, both as already reported it can be calculated that of the test bodies frozen without collapse or constraint of the outer walls the percentage of voids should be

$$S = 100 - (13.46 + 0.1139 \text{ C} + 0.0568 \text{ Si}) \rho_T$$

In this ρ_T has the value given in the next preceding equation, the temperature T being the mean temperature of the test body at the moment when the gate freezes off.

Substituting a plausible value of T , 1450 degrees Cent. for example, in the formula for q and the resulting value of q in the formula for S we find

$$S = 4.35 + 0.1328 C + 0.910 Si + 0.015366 C Si + 0.00568 Si^2 + 0.007973 C^2$$

We may eliminate the terms of the second degree by substituting for C^2 the nearly equal value 2.5 C , for Si^2 the nearly equal value 0.8 Si and for $C Si$ the nearly equal value 2.0 and obtain the equation

$$S = 4.38 + 0.153 C + .915 Si$$

which is the same form as that finally derived in the paper. The possible range in carbon content for the material studied is about 1 per cent (from 2 per cent to 3 per cent) and of silicon content 0.5 per cent (from 0.6 per cent to 1.1 per cent). It will be seen that by calculation this variation in carbon should be attended by a variation in density of 0.15 while the observed variation is 0.398 per cent. For silicon the calculated and observed variations are 0.91 per cent and 1.22 per cent respectively. Metal of average composition, carbon 2.50 per cent, silicon 0.80 per cent would have a shrinkage calculated from the density data of 5.5 per cent and calculated from the shrinkage experiments of 1.04 per cent.

It will thus be seen that the shrinkage ball test shows a greater effect for both carbon and silicon than does calculation from the liquid iron data. Had we taken the Honda data, showing no effect of silicon on density the result would have been still worse.

The much smaller observed than calculated shrinkage points either to considerable collapse of the sphere walls, of which relatively little was observed or else to too low a value for the density of liquid iron. The Honda and Endo data are in general lower than ours so that their data again would not give more plausible results for shrinkage.

It may be observed that the shrinkage equation is of the order of magnitude of

$$S = 100 - 13.9 Q_r$$

a discrepancy of 4.5 per cent in shrinkage is equivalent to a difference of about 0.32 in Q_r .

In view of the concordance in values in Table 1 and their order of magnitude this is considerably beyond the apparent experimental error.

In what has just been said the initial temperature has been taken at 1450 degrees Cent. If the true initial temperatures be lower than this, as they may perfectly well be the error will be compensated.

From the formula for Q_r it follows that a change of 1 degree Cent. alters this value by 0.0022, hence to produce a change of 0.32 will require that T be lowered by about 150 degrees Cent. or to 1300 degrees Cent. which is by no means an improbable value. Since a part of the body is solid the correction is actually a little less and the initial temperature may be correspondingly greater.

It has thus been shown that the results of the shrinkage experiment are quite possibly in accord with the values calculated from our density deter-

minations and that the effect of carbon and silicon on shrinkage is found experimentally to be somewhat greater than by calculation though of the right order of magnitude.

It was pointed out in the paper that there is a probable error of about 0.20 in the agreement of the observed shrinkage values with the formula calculated from these data. From the relation of density to temperature in the liquid this corresponds, if due entirely to fluctuations of temperature, to a variation of temperature, from the average, with a probable error of 90 degrees Cent., and of course with a maximum variation larger than this by an unknown amount since we do not know the distribution of the variation.

Since we observed the great effect of pouring temperature on density it seems reasonable to assign as a major factor in the unaccounted for shrinkage variation the unrecorded variations in temperature. Consideration of the cooling rate of our test body and gate, regarding the latter as cylindrical, as solids cooling by radiation, a condition which is perhaps approached, suggests that our gates freeze up (at about 1250 degrees Cent.) when the mean temperature of the sphere is about 0.96 times the temperature at which the metal fills the mold. The errors in the assumption are probably such that the value 0.96 is a little low. Evidently, therefore, changes in pouring temperature find expression, almost unaltered, in the initial temperature from which shrinkage occurs. These pouring temperatures may readily vary 50 degrees Cent. or more from the average and thus account for much of the variation in shrinkage.

Gray Iron Foundry Practice and Cupola Operation

Three papers were presented before the session on Gray Iron Foundry Practice and Cupola Operation. The first, "Science Hand in Hand with Labor" by F. Hudson, will be found beginning on page 417; the second, "A Study of 36-inch Cupola Operation" by F. B. Coyle, will be found beginning on page 21, and the third, "An Analysis of 54-inch Cupola Performance" by E. E. Marbaker will be found beginning on page 71.

DISCUSSION—SCIENCE HAND IN HAND WITH LABOR

J. T. MacKENZIE: On page 425 Mr. Hudson mentioned the present day tendency for total carbon content below 3 per cent. There was a very definite swing to total carbon content around 2.75 and even as low as 2.50 per cent, but certainly the continental practice has reverted to carbons above 3 per cent. It has been found that with correct pouring and gating practice the fluidity or casting properties of the 3 per cent carbon iron was so much superior to the very low carbon, that you really obtained a better casting although the test bar might not have been so good. They discovered, as we did some years ago, that you do not get any money for test bars..

Referring to page 443, we ran into a point in oil and sand cores that I have never seen in print. If you run the same pattern for a test bar in oil sand and in loam sand, the dimension of the bar cast in the oil sand will be some 5 to 12 per cent smaller than the same bar cast in loam. In soft gray iron, 3.50 carbon, 1.50 silicon, the metal is actually squeezed out on top to a very pronounced extent. Now the actual breaking loads from the same pattern were, in the case of the mixture we tried, 2,600 pounds for the test bar cast in molding sand and 2,100 pounds in the case of the metal cast in oil sand. The corrected load showed only some 200 pounds in favor of the molds that were made in loam when reduced to standard dimension. I attribute that to the squeezing action of the oil sand on metal in the freezing range and the possibility of small cracks. I would like to know if anybody else ever ran into this problem.

MR. TULMAN: May I ask Mr. MacKenzie how he poured his bars?

J. T. MacKENZIE: Vertical, over the top.

MR. TULMAN: In our experimenting, we found you were just about right. We had that great variable and could not see where it came in, and

in a bar cast 1x2, we got just about the same results that you are speaking of.

CHAIRMAN R. F. HARRINGTON: Did you attempt to offer any explanation as to the difference in the metal quality that would permit of lower figure?

MR. TULMAN: I am sorry to say no; I wish I could.

J. T. MACKENZIE: The shape of the bar cast in oil is very distinctive. The bar cast in loam will be a rectangle with the corners a little rounded off, on account of the flowing properties of the blacking; you never get one exactly rectangular, whereas the oil core will show sharp corners and be concave on the sides, showing very distinct pinching and squeezing action from the four sides of the oil sand core. Now, I assume that if the velocity of freezing was greater, or if the surface froze before the pressure of the oil came on it, you would not have that condition, but we have cast parallel bars as small as an eighth of an inch section and still find the same thing.

R. S. MACPHERRAN: On page 421 there are listed four different kinds of semi-steel; semi-steel, soft semi-steel, semi-steel for high pressure castings, and then hard semi-steel. Those carbons vary from one to three and a half per cent. How much steel does Mr. Hudson use to get those results?

O. SMALLEY: He says in the paper that he uses 10 per cent steel, but he also makes another reference in regard to those irons that is quite instructive; that is, by the use of chilled cast pig iron he controls the total carbon in his metal. Hudson uses refined cupola pig iron, and so, starting with something specific, both in the chemical and physical characteristics of his pig iron, also with controlled cupola conditions, he is able, more or less, to keep a pretty good control of his total carbon. To make the pig iron, Hudson uses a common hematite iron and about 70 per cent steel scrap.

R. S. MACPHERRAN: Years ago the Americans used to make what they called cupola pig and charge their special iron with this cupola pig. I believe Mr. Hudson must follow the same practice.

O. SMALLEY: Mr. Hudson says manganese should be constant around 1 per cent. In my own experience in making semi-steel, I find that if the manganese falls below 0.60 per cent, there is a tendency to get what one might call shrink draws. Mr. Hudson refers to porosity due to expansion. By using a low carbon semi-steel you do not get that expansion, but instead a shrinkage like the pipe in steel ingots. By increasing the manganese to 0.6 or over, you can appreciably reduce this defect. So far as the ration of ten to one of manganese to sulphur, I presume that is to compensate for the sulphur. In my own experience, I have no difficulty in handling 0.2 per cent sulphur with 0.6 per cent manganese. I would like Mr. Hudson to tell us why he used 1 per cent of manganese.

J. T. MACKENZIE: I think it should be remarked at this meeting that this is an excellently written paper and really has stated the case so well that there are very few points to which exception can be taken.

DISCUSSION—A STUDY OF 36-INCH CUPOLA OPERATION

WRITTEN DISCUSSION—PRESENTED BY F. HUDSON

This paper is a very valuable one, and should help considerably to forward the present day need of uniform and precise cupola control. I am particularly glad to notice that the composition desired is identical to my own experience. Without depreciating the value of this work, one feels how very much more valuable the results would have been if the blast volume readings had been given in conjunction with blast pressure. Pressure readings by themselves are of very little value in cupola control as they only denote air pressures existing inside the furnace or wind-box, and it by no means follows that high air pressures represent large volume. In fact very often the opposite is true. For example, obstructed tuyeres will give rise to high blast pressures with low volume, while the use of bulky material composing the charges will give rise to an exact opposite state of affairs. Accordingly I cannot quite agree with some of the assumptions based upon blast influence as the blast volume must essentially be noted. In this connection Mr. Coyle's finding that "increase in blast pressure lowers total carbon" cannot be generally accepted unless the increase in blast pressure is accompanied by increase in blast volume. Again, hot iron can be produced from a slow melting furnace to give a high total carbon content while the same temperature can be obtained on fast melted iron from the same furnace with the production of low total carbon material. This again is not quite in agreement with the finding, "The higher the temperature the lower the total carbon." The atmosphere existing in the melting zone plays a very important part in the carbon absorption question, and this again reverts back to the importance of blast volume control.

D. McLAIN: On page 43 Mr. Coyle draws attention to the fact that the best melting, the best and the strongest metal was produced when the bed was about 24 inches high. I have claimed recently that there is more coke used today per ton of iron melted than was used when coke sold for \$1.00 per ton. About 50 per cent of the reports we receive in our office indicate that to be a fact. There are heights of forty inches and forty-six inches of bed. We have received several reports of fifty inches of coke on the bed. It seems ridiculous, still they have the reputation of being good foundrymen and produce good castings.

J. D. STODDARD: A rather bold statement was made in the paper regarding the fact that no increase in sulphur was obtained from the increase in the amount of returned scrap. Any foundryman taking that as a general fact without explanation, might think that he might use all scrap and yet get no increase in sulphur in his castings. I believe the experience of every foundryman has been that the higher percentage of returned scrap material used would invariably increase the percentage of sulphur, provided you do not change your cupola practice when that increase is made. I think there is a question there that should be explained or made clear, for some foundryman might try to melt nothing but scrap.

F. B. COYLE: That point is very well taken. The material manufactured averaged 0.10 to 0.12 per cent sulphur; the returned scrap averaged 0.10 to 0.12 sulphur. It is noticed that even using the 20 per cent of returned scrap, the sulphur would begin to range 0.10 to 0.12. It goes without saying, that if you were using materials which would indicate obtaining about 0.07 sulphur and used the higher sulphur returned scrap, 0.10 or 0.12, you are bound to get a higher sulphur. In this paper merely a record was made of the experiments conducted and only general conclusions from these experiments were given. It is probably a foundation for future work, but it is not to be taken as a guide of definite practice, that would be an error. It is a foundation to show a method of study. Really what the paper was intended for was to show this method of studying these conditions and suggest that it might be advisable for others to investigate in the same manner.

J. T. MACKENZIE: The question of sulphur absorption would very probably depend on the character of the return that Mr. Coyle had. In the British Exchange Paper for 1926 I described three melts, using the same coke, the same blast, and the same material. In one melt, the steel charged was a three and one-quarter inch round; in the second, it was a three-quarter inch round steel, and in the other it was an eight and one-quarter inch strip. Now, in that case the sulphur in the charge and the sulphur in the coke was all the same, but the three and one-quarter inch round tapped out at 0.10, the three-quarter at 0.12, and the eight inch strip tapped out at 0.15.

P. T. BANCROFT: I might state that during the war period there was quite a bit of discussion in regard to the high point of sulphur and that, charging it back in our cupola, our sulphur would keep pyramiding and building up. To my knowledge, in my foundry, my sulphur, to my surprise, is not much higher now than it was then, and we have undoubtedly melted a great deal of that high sulphur return scrap from the war period. Our remelts are going in day by day and the high sulphur very seldom gets above 0.10; once in a while it gets up to 0.12, and we have had it much higher than that.

F. B. COYLE: On the subject of sulphur, it might be interesting to cite some results we obtained at the Pratt and Whitney Company several years ago. Sulphur varied from 0.06 to 0.18 per cent. The effect of sulphur on tensile strength was studied, and it was clearly indicated that as the sulphur increased from 0.06 to 0.14, the tensile strength increased to a maximum. With 0.13 to 0.15 sulphur, there was practically a maximum of tensile strength obtained. As the sulphur increased above 0.18 the tensile strength decreased.

J. D. STODDARD: I think this point that Mr. MacKenzie has brought out is of great interest, and probably his solution is the correct solution. The increased sulphur found in those different charges consisted in metal of different section thicknesses. It is a question that has been of great interest to students for a good many years.

There is one point made here which I think is open to discussion, that is, that the sulphur in iron is absorbed at the time of its melting in the cupola rather than by coming in contact with the coke before the melting process starts. All of us who have had any experience with the analysis of grate bars know something about how metal absorbs sulphur in very excessive quantities before it ever reaches the melting point. My understanding is that the sulphur is absorbed in the iron when it is at a bright red heat, and I believe that it is correct to state that sulphur is absorbed before melting actually takes place in the cupola.

W. E. GOULD: On this last point of the absorption of sulphur—I made a test once which will perhaps have some bearing on this. Taking a billet of iron which I had analyzed as 0.02 per cent sulphur and placing it in a large bed of incandescent coke, I kept it at red heat for 12 hours, and then took a sample from it when cold, and it came out 0.02 per cent sulphur.

O. SMALLEY: Where did you take your sample from for analysis after you had soaked it in your coke?

W. E. GOULD: I took a sample of the whole billet.

O. SMALLEY: Brearly took some samples of steel and heated them in sulphur gases at various temperatures. He proved that sulphur is absorbed by steel at temperatures above 1000 degrees Cent.

MR. MORRIS: To get back to the subject of scrap and pig iron in the cupola and changes in the sulphur, due to the melting pressure, we were running normally a 0.065 to 0.075 per cent sulphur and conditions were such as to cause us to increase our coke ratio. We had been having too high sulphur, which was not desirable when melting 50 per cent of our own return, and 50 pig, so we had the happy idea that if we melted all pig we would get lower sulphur. To our surprise we melted this charge of pig and found that the sulphur came out the same as when we melted half scrap and half pig.

A. D. SMITH, JR.: In regard to heat 33, on page 27, and the amount of pig iron used. You have said that you use some Mayari pig iron in that mixture enough to give .25 chromium and .25 nickel. Is that statement correct?

F. B. COYLE: Yes.

A. D. SMITH: Did you use some other nickel in connection with it?

F. B. COYLE: No.

A. D. SMITH: I just wondered, because this practically would make it necessary to use 75 per cent of Mayari pig iron in the mixture.

F. B. COYLE: The first part of that particular heat was conducted by a foundry engineer who was interested in that particular pig iron and was entirely calculated, adjusted, etc., by him. It was intended to add 0.25 per cent with Mayari pig iron, running 2 per cent of nickel and 2 per cent of chromium.

A. D. SMITH, JR.: You would have to use 75 per cent of pig iron in the mixture?

F. B. COYLE: No, 15 per cent.

T. F. KILEY: I would like to ask what is the order of charging pig iron scrap and steel?

F. B. COYLE: There was no order, it was all mixed right in together.

T. F. KILEY: The reason I asked that question is that we used to be told to charge the steel scrap on the coke. Recently we were hearing about charging the steel on the pig iron.

DR. R. MOLDENKE: That would depend a good deal on the size of the steel and pig iron. I prefer to put the steel on the coke, because to get the steel to melt readily, it must have contact with coke. If you put the steel on top of the scrap, or on top of the pig iron, you will find the steel in the next charge, because the scrap and pig iron will melt away and leave the steel behind.

T. F. KILEY: Some of us say that steel, a quarter inch section, will melt before pig iron.

DR. R. MOLDENKE: I believe there is a good deal in what Mr. MacKenzie said about the amount of surface to the weight. The charge should be as small as possible. What you want to try to do is to get the mixture down uniform. Steel takes a higher temperature to melt; pig iron takes longer to absorb heat; scrap melts quickly; if you charge steel, pig and then scrap in that order they will melt together.

The thickness of the steel has a great deal to do with the position in the cupola; very thin steel could go on top of a charge, but a heavy piece of steel wants to go at the bottom of the charge where it can be washed away by the melted pig and scrap. I have seen cupolas dumped where part of the steel dropped out unmelted; it went down into the bed and the washing action of the scrap and pig above it was not enough to melt it completely.

MR. GEASEY: I would like to ask Dr. Moldenke where he considers the proper place to charge steel ranging from one-quarter to one inch in thickness on the coke bed?

DR. R. MOLDENKE: I always put steel on the coke. Incidentally it is very difficult to discuss Mr. Coyle's paper, because all through it there runs the question of high pressure and low pressure blast. This means that the position of your melting zone is varied all through. Did you change the amount of air going in to get these different pressures?

F. B. COYLE: No, only on successive heats. The pressure was varied only on one or two heats to try and find out how the melting conditions through the heats were varied by a variation of pressure. On all the rest of the heats, the pressure was maintained constant in order to get a uniform volume of blast throughout the heat.

DR. R. MOLDENKE: That is the difficulty; you talk about pressures being raised, etc., even during the same heat. This means that you ran your blower faster or slower and thus varied the volume of air blown into the cupola in a given time.

F. B. COYLE: But you will find that answered on each one of these diagrams. For instance, on page 29 the blast pressure is shown as between 8½ and 9 inches throughout the entire heat.

DR. R. MOLDENKE: But another heat has a different pressure?

F. B. COYLE: Yes.

DR. R. MOLDENKE: In other words, you changed the amount of air you blew in there without changing the position of the bed?

F. B. COYLE: Yes.

DR. R. MOLDENKE: Therefore you must have been melting in different positions of the cupola for the same charging. Different pressures necessitate different volumes of air being blown in the cupola, and that would mean that if you did not change the bed height accordingly, you would get different melting temperatures. The point is to get the best position for good melting.

F. B. COYLE: That question was brought out in this paper when it was stated that at that time the only means of measuring the blast was by pressure, but it goes without saying that the amount of the blast used in the cupola should be measured by either volume or weight or some more exact means.

O. SMALLEY: There are two points Mr. Coyle mentioned that ought to be cleared up. He said if you melt at about 2,730 degrees Fahr., etc.—Piwowarsky makes that claim, too. I would like to say that it is only a claim and such temperatures have never been actually measured. It would be a nice thing if you could melt cast iron and melt it at 2,700 to 2,900 degrees Fahr. under ordinary cupola conditions. Various other workers claim to do this, but invariably their temperature readings are made by an optical pyrometer and are not accurate. The next point I want to mention is that Mr. McLain makes an open challenge about the high coke bed. The results Mr. Coyle gives regarding the 22, 24, 26 and 28 inch effective bed, I think, are meaningless. Variation in size of the coke could alone be responsible for the results given. I would never start with a bed under 36 inches if I want hot and fluid metal. I have met many men who use 24 inch beds. They usually find that in the middle of a heat the temperature falls off and they begin doubling up their coke. I do not think you can get proper temperature, control and economy in your cupola practice unless you start with a bed of sufficient height to get correct combustion of the coke. Also, if you start with right coke bed and the correct proportions of coke between your charges, you do not have to add extra coke between charges.

D. McLAIN: I maintain that if you have a 36 inch bed or higher, you have high blast; we proved conclusively twenty-five years ago that when we had the Connellsville coke, a hard dense structure coke, we melted our best iron at 18 and 22 inches. We now burn a lighter coke, the by-product coke, with our blast under control, although very few have it under control today. We found that with coke 22 to 26 inches above the tuyeres, it gave us the best, the hottest iron. It is true on longer heats, I don't care if you have 60 inches coke on the bed, that you should add more coke every four to six charges on the long heats. That is my thought, to maintain your bed at the right height, whatever that height may be.

F. B. COYLE: In answer to Mr. Smalley, if he will look at page 43, at the middle of the page, he will notice that the presentation of that diagram with reference to the bed of 24 inches has been qualified as follows: "While this low bed will not be considered orthodox, it gave the best results in this case, and, after all, results are what count."

J. D. STODDARD: This height of bed is the most interesting one to any foundryman who takes any pains with his cupola operation, but it makes a difference whether you put in three-quarters or two-thirds or one-half the coke that is going into the bed and burn that and then add the rest, and measure it. You are going to get entirely different results if you put in three-quarters and even more than that and light it up and let it burn through before you add the balance. You are going to have a partially burned bed of coke that is much more dense than if you put in only half the amount of coke that is going in the bed and then level it off.

I quite agree that 24 inch beds have been run with excellent results on certain cupolas. I have tried to run them with similar practice in other cupolas of the same dimensions and failed to get good hot iron and had to add extra coke to bring the temperature up where it was desired. Each cupola is a problem by itself, and the practice and details that surround this operation must be taken into consideration.

I maintain that the great danger of young experimenters and investigators today is that they are prone to jump at conclusions from one series of tests which they have conducted. They do mean something as relates to that particular test and are of interest, but we all have to make reservations, because we have all had air castles built and thought our conclusions were correct and our troubles were over. Then along comes a different proposition which we thought ought to give the same results, but the results do not agree, and we have to change our conclusions.

J. T. MACKENZIE: One point I do not get is the diagram on page 47. Mr. Coyle makes the statement that cold iron gives higher carbon; in his graph there on page 47, Fig. 4, he shows that the carbon falls off with the melting rate, which is orthodox, but that at the low temperatures he gets very much greater carbon absorption. Now I cannot reconcile that. I can readily see where, with a slow rate of melting, the metal as tapped would be cold, but it would have a high carbon because it melted at a higher temperature originally, but I cannot see that the low temperature would run consistently higher carbon if the melting rate was the same. Possibly Mr. Coyle can explain that. And I would also like to know how many points there are on that graph? Mr. Coyle did not show the points.

F. B. COYLE: There are probably sixty or seventy points on these three graphs. That particular graph was constructed from about sixty heats altogether, the eighteen heats being augmentive. The diagram presents a problem for explanation. There has been no attempt in the paper, and the speaker has made no attempt to explain why that diagram is as it is, and I would be very much pleased if somebody else could explain it for him. This whole paper is merely a presentation of the data as it was observed.

I. E. WAECHTER: There is considerable talk about pressures in the discussion of this paper. Dr. Moldenke mentioned that pressures do not count for anything, it is the volume that counts. I quite agree. This particular correction, of course involves tuyere ratio, which has not been mentioned as such, but implied in his correction of volume and not pressure to be considered. The whole problem reduces itself to tuyere ratio, as to just what pressure you will have in the cupola. You have a certain amount of volume of air entering that cupola, and that is governed by the size of the cupola, by the rate of capacity and the capacity at which you operate your cupola. We have two cupolas in the foundry I am connected with. One, which was there before I came, is still operated with the same tuyere ratio. The other I recently installed, the tuyere ratio of which I calculated, I am operating it at what I consider rated capacity to give very good results. The cupola I installed has a tuyere ratio of about four and one-half to one, i. e., 22 per cent. I am melting with a bed of about twenty-two to twenty-four inches above the tuyeres, getting excellent results, using by-product coke. In the other cupola, having tuyeres which are, in my estimation, not quite right (a condition which, by the way, I expect to rectify shortly), I have to have a thirty-three to thirty-six inch bed to operate properly to get hot iron, and to operate it to capacity. The difference there obviously is nothing else but pressure as a result of difference in the tuyere ratio.

MR. RAMEY: Perhaps I should not say anything at all before this gathering, because in the first place I am a blast furnace man. But the matter of pressure, tuyere area, are relationships which appear to me to be worth a remark which may interest you just at this time, for the reason that I saw a very remarkable experience at a well-equipped foundry within the last ten days. Probably the most experienced foundryman here will consider that a ratio of tuyere area to cross section of cupola of anywhere from twenty to thirty-five per cent is well within the range of good practice. When you get down to a ratio of about 15 per cent, you will think that is on the danger line toward the low percentage, but, gentlemen, I have seen excellent iron taken from a cupola with a tuyere ratio of 7 per cent when the pressure was reduced to six ounces. In my rather long observation of foundries, because my business takes me into foundries occasionally, I have never known a tuyere ratio of 7 per cent; 14 and 15 is the lowest I ever had heard of or knew, and I condemned it out of hand, but when I saw this 7 per cent, I also condemned it. In this case a very large cupola, about ninety inches in diameter, was found to be too big for the continuous melting process; so it was relined down to about 54 inches. The large tuyeres were taken out and a number of four and one-half inch pipes installed to get penetration to the middle of the stack. At once the iron came down quick and hot, and sound, and made good castings. Those matters of pressure in tuyere area are relative rather than absolute. That is the substance of my remark, and I think you will agree that a relationship is the proper way to consider this matter of pressure rather than the absolute pressure, and it has relationship to the diameter of the cupola, which

has to do, of course, with the matter of penetration of your coke. I have seen a steel bar put across a blast furnace from one side to another, and inside that blast furnace there was a temperature somewhere around three thousand in front of the tuyeres. That bar was put right across that blast furnace in one tuyere and out the other, and it was black in the center, indicating a lack of pressure of wind through those tuyeres to the middle of the stack to produce the high temperature necessary to equalize the temperature throughout the crucible. The same condition maintains sometimes in your larger cupolas, where the area is too large in proportion to the blast pressure.

AUTHOR'S CLOSURE: On page 23 of the paper the author stated that the results of the study were presented for the purpose of stimulating discussion and further investigation. The author realizes that this study was carried out under limited conditions and has only attempted to present an interpretation of the various factors resulting from these conditions. The author would hesitate to draw general conclusions from the data presented. Several facts arose during the discussion which, from the interest shown, are worthy of further investigation. In the author's opinion they can be listed as follows:

- (1) Sulphur absorption
- (2) Tuyere ratio
- (3) Blast volume and pressure
- (4) Method of charging
- (5) Material charged
- (6) Temperature of melting
- (7) Rate of carbon absorption

The author further believes that if a number of investigations of this nature can be conducted and published, that the pooling of such data will enable drawing general conclusions which will aid in increased cupola efficiency.

DISCUSSION—AN ANALYSIS OF THE PERFORMANCE OF 54-INCH CUPOLAS

L. E. WAECHTER: I should like to ask Dr. Marbaker about the size of the cupolas where he had the high thermal efficiency, 61, and 53 per cent, respectively, and whether those cupolas are operated at the recommended rated capacity, and further, whether the height from the sand bottom or from the tuyeres to the charging door is standard and whether the height of the shaft above the charging door is standard or special, and what he assumes is the reason for the high thermal efficiency compared with the cupolas that he just discussed?

DR. E. E. MARBAKER: The cupolas I have in mind are two in number; they are absolutely standard in every respect. The only change I know of which has been made is that there is a ten inch space between the slag hole and the tap hole, so that a ten inch body of iron can be held in

the hearth. The distance from the bottom doors to the charging doors is normal; I believe that it is between eighteen and twenty feet.

I. E. WAECHTER: What is the height of shaft above the charging door?

DR. E. E. MARBAKER: I do not see that that has anything to do with it. As a matter of fact it is probably thirty feet. Nothing visible goes out of the stack; I only wish I could get some gas analysis on this cupola; that is the only thing we lack in the way of data; if we could get gas analyses, I think we would be able to tie up this whole thing very nicely with what you might call the internal evidence. Is that all?

I. E. WAECHTER: I was wondering if they did something special? Are the cupolas operated at their rated capacity?

DR. E. E. MARBAKER: I will tell you what the special thing is; the special thing is an infinite attention to details. Every charge is weighed, coke and iron alike. The general nature of the charge, the pieces of which are comparatively small, is such that a great deal of surface is exposed. The weights are accurate; when they say they charge two thousand pounds of iron, it means two thousand pounds, not nineteen ninety or two thousand ten, and the same goes for the coke.

DR. E. E. MARBAKER: The cupola has a 78 inch shell, and has been lined down from time to time to accommodate the conditions of the molding floor to forty-six inches, from forty-two to forty-six inches. The lining is therefore quite thick.

DR. R. MOLDENKE: Just to complete the information about those specially good cupolas—tell us what kind of castings they make. The point is this, if you melt in that part of the melting zone where you have the maximum $C O_2$ you will get an excellent heat efficiency, but the iron may also come in contact with free oxygen; consequently, if you have to make castings that require ready machinability you will have to sacrifice some of this efficiency to be sure that they are not oxidized.

DR. E. E. MARBAKER: That has been carefully considered, and the results realized take care of the point Dr. Moldenke has brought out. I may say that the one inch transverse strength bars on twelve inch centers, break about 3,400 pounds. The iron is a high silicon iron which is made to be machined readily; the castings are small; the heaviest section is about one-eighth of an inch. Does that answer the question?

DR. R. MOLDENKE: When you machine those castings, will they show up perfect?

DR. E. E. MARBAKER: They do; there are no hard spots. I saw them do this out at the plant; they pile a number of these small castings, one on top of the other, and then the pile is drilled very rapidly indeed.

A MEMBER: In an efficiency like that, they must have access to a uniform grade of scrap also; that is an item which enters vitally into an efficiency of 61 per cent. You could not get that with one source of scrap today and another tomorrow; they must have access to good scrap and have it every day.

DR. E. E. MARBAKER: Well, I think that is in line with the rest of the operation; I think they see to it that the quality of this scrap is kept uniform.

I. E. WAECHTER: The question was whether those cupolas, lined down as they were, operated at their rated capacity?

DR. E. E. MARBAKER: It is a little higher than the rated capacity, but the cupola is boshed, and I haven't got it straight in my mind how the boshed cupola should be rated. Are you going to take the average diameter of the bosh or the minimum diameter of the bosh?

I. E. WAECHTER: What was your tuyere ratio?

DR. E. E. MARBAKER: It is about 25 per cent.

DR. R. MOLDENKE: Speaking about the boshed cupola, the real reason of boshing a cupola, as I take it, is this: when you have a very long continuous heat, you must either bosh out in order to allow your lining to eat back or you might run through your cupola. Were these long heats?

DR. E. E. MARBAKER: Yes, these heats ran about nine hours, and, of course, I realize that is one of the reasons for the high efficiency at this particular plant. At 105 tons daily yield from the cupola, the melting ratio is 16 to 1; but if they only want to melt about 75 or 80 tons a day, the efficiency drops off to about 14 to 1, and a calculation is given in the paper which shows you how that is arrived at.

MR. SWEELY: I would like to ask Dr. Marbaker where is the best place to analyze the gases, at the cupola door, the charging door, or at the top?

DR. E. E. MARBAKER: I would say that if you would sample the gases at a point just a trifle above the melting zone, you would be doing it at the right place. If you get up to the charging door, or a few inches below, where very often samples are taken, you are going to be bothered by air which will upset the whole ratio of O to CO₂. For instance, if you made the analysis from gases taken just below the charging door, you would probably find an excess of oxygen. Now, the sampling of gases from the cupola is a very serious operation, to get a fair sample. There have been two or three papers written in the past on that subject, which I would recommend. There is the more or less classical paper of Belden, published* under the auspices of the Bureau of Mines along about 1914, and there have been several German papers written in which the actual gas analyses were recorded and the carbon dioxide and the carbon monoxide ratios were given. A great many people think that a ratio of carbon dioxide to carbon monoxide of, say, 1 to 1, would indicate fairly good cupola operation. Others think that a ratio of two of carbon dioxide to one of carbon monoxide is best, but the German investigators report results of the order of eight parts of carbon dioxides to one part of carbon monoxide, which is a great deal closer to theoretical combustion conditions.

DR. R. MOLDENKE: Those German reports all refer to very small cupolas, however, do they not?

*Material republished as *Foundry Cupola Gases and Temperatures*. Page 1, Vol. 22, Transactions of the American Foundrymen's Association.

DR. E. E. MARBAKER: Yes, everything is small in Germany. Take a cupola lined to 96 inches. I would hate to have the proposition handed to me of getting a fair sample of gas out of that cupola anywhere, so I would say this, I think that the use of a volume gauge and determining the amount of air definitely going into the cupola, combined with the amount of coke you are going to burn to melt a certain amount of iron, will give you the results you are after without making the gas analysis necessary. That is getting at it through the back door, but it is a lot cheaper and easier.

DR. R. MOLDENKE: You spoke about a second row of tuyeres. I want to say that my own experience is this; you can get hotter iron with a second row of tuyeres because you extend the melting zone so much more, but you have a serious question of about what kind of castings you will get, and whenever you have to have light castings that have to be machined easily, you will generally have trouble when using two rows of tuyeres.

DR. E. E. MARBAKER: This very excellent cupola I have been talking about was supplied with the upper tuyeres and has been used with the upper tuyeres, never any change made at all. The other cupola which operates at about 53 per cent efficiency, on cast iron pipe, is operated without upper tuyeres. Now, the difficulty with upper tuyeres, in a general way, is that the distance between the lower and upper tuyeres has to be so regulated that there is no danger of getting a second melting zone. If that distance is maintained at the proper point, then I believe the upper tuyeres will be of some use.

I. E. WAECHTER: The question I asked before relative to the dimensions of these two splendidly operated cupolas was prompted by an experience I had several years ago in quite a large plant. I was in charge of the cupola operation and was criticized by the combustion engineer, who was not responsible for the cupola operation, on the ground that combustion, in his opinion, was not very good. Of course, he compared cupola operation with boiler operation or other combustion problems. At the same time, at that same place, we had some trouble with some of our cupolas issuing very hot sparks, burning off the roofs of houses in the vicinity. This combustion engineer thought he would solve both problems at the same time, thereby giving us better thermal efficiency in the cupola and stopping the burning off of the roofs. We carried on considerable investigations, taking gas analyses, but probably not at the proper places above the melting zone, and made a thorough investigation as to heights above the charging door, and everything else, and the recommendation that we got from this combustion engineer was to cool our gases and to cool the charge from the very top of the shaft by sprinkling some water, thereby saving some of the B. t. u.'s in the gas going up and probably some of the water coming down on to the charge at the charging door, that we could save considerable B. t. u. The fact of the matter was that we did not accomplish very much on that basis. The thing that we found out was

that we operated our cupolas at too high a blast. That was the reason for our high coke beds. Reducing the blast reduced our coke beds, the operation of the cupola became more efficient at once, and operating it at the lower blast reduced the sparks on top of the cupola, which in turn reduced the burning off of roofs in the vicinity. I was just wondering in connection with this whether anyone here had any experience of this sort, where he has tried to do something else besides the regular things in the foundry to try to obtain greater efficiency?

J. GRENNAN: Dr. Marbaker has made an excellent analysis of the performance of cupolas from the data he has gathered. The question of gas analysis has been brought up in this discussion, but there was no gas analysis available for him to use in his paper.

We have been trying to get something in regard to the composition of the gases discharged from the cupola. There is considerable difficulty in collecting the gases and considerable difference in the analysis of the samples taken one after the other from the same location in the cupola. We have found that in several cupolas in the Detroit district the gases taken about a foot below the top of the charge were composed of about equal volumes CO_2 and CO . The best results and also the worst results were found in our own cupola. With one coke, the gas analysis showed 14 per cent CO_2 and 10 per cent CO . Another coke gave a gas analysis of 10 per cent CO_2 and 16 per cent CO . Using Dr. Marbaker's figure of 14,550 B. t. u. per pound of carbon burned to CO_2 and 4,450 B. t. u. per pound of carbon burned to CO , the difference in fuel value between the two cokes in terms of B. t. u. per pound of carbon would be 10,341 B. t. u. and 8,331 B. t. u. This compares closely with a melting ratio of 10 to 1 for the better coke and 8 to 1 for the poorer coke.

Quality of Pig Iron and Cast Iron as Affected by Blast Furnace Practice

Only one paper was presented before the session on Quality of Pig Iron and Cast Iron, which was by A. L. Boegehold. This paper may be found beginning on page 91.

CHAIRMAN H. W. GILLET: Those of us who are concerned with metallurgical research hear a great deal about so-called fundamental and applied research. I always feel that there is no difference if either type is properly performed, for then you can't tell one job from another. It is interesting, however, to consider the statements of people who claim that all fundamental research ought to be done by universities or government laboratories.

Now, if you just stop to think what this particular work of Mr. Boegehold meant in the amount of metal melted, the labor costs and so on, you can see that it was only economically possible when there was a place to use the product. If some university should try to do this work that Mr. Boegehold has done, they, not making automotive fly wheels, would have had to scrap all the metal they melted.

Therefore, it is necessary for the advancement of metallurgy that problems of this sort be handled by the research laboratories in our industrial organizations, and it is a very promising sign of the times when a group like the General Motors organization undertakes a fundamental proposition of this sort, because no firms outside of the class of the General Motors Corporation can do it. I think we all owe a very great debt to Mr. Boegehold and the General Motors Corporation for attacking this problem, which is of so much value and interest to all of us.

(Written discussions were then presented.)

WRITTEN DISCUSSION—SUBMITTED BY H. A. SCHWARTZ*

Mr. Boegehold's paper is one of the most interesting the writer has encountered in recent years. If, then, criticism is offered, it is not with the intention of minimizing the importance of the author's work but for the purpose of increasing that value by pointing to omissions which if supplied or explained will still further increase the paper's importance.

Many of the properties investigated by Boegehold are obviously, in large measure, expressions of combined carbon content, all other things being equal. Perhaps fluidity is the only one of the properties enumerated on page

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96 which can not be definitely correlated therewith. Permanent growth also, to which the author refers later, is in major degree determined by a graphitization during heat treatment.

On page 128 the author discusses a relation between blast conditions and the resulting combined carbon, clearly recognizing the latter's importance. Yet we find no attempt recorded to correlate the various observations with that constituent, an oversight much regretted by the commentator. It would appear that the author's problem was to determine whether iron of given composition varies in properties according to its origin and no conclusions on this point can be had until composition is extended to include separately free and combined carbon. There may exist also the incidental problem as to whether or not iron of given ultimate composition and thermal history differs systematically in combined carbon according to its blast furnace origin. Except that we can not distinguish quantitatively between the effect of blast furnace and cupola conditions Fig. 11 answers the second question affirmatively, although even here there is no evidence as to whether or not the changes in blast moisture are accompanied by changes of silicon or total carbon sufficient to account for the observed facts.

The present writer would also recommend particularly an analyses of the various strength and hardness data from the view point of graphite and combined carbon rather than on the basis of silicon or the empiric carbon plus $\frac{1}{2}$ silicon basis selected by Boegehold in common with many other gray iron metallurgists.

Following the changes in combined carbon accompanying the dilatometer heat treatments might have shed light upon the observation that large dilatometric changes in passing (upward?) through the critical range are accompanied by small permanent growth.

In Fig. 14 the author has found it necessary, in support of his views that blast moisture affects machinability, to explain that the points falling above and to the left of the diagonal lines drawn by him are from slow running furnaces and those below and to the right from faster running furnaces. Without this explanation we would draw the conclusion from the points plotted that blast moisture has nothing to do with machinability. We are thus led to the conclusion that oxygen from the descending ore burden affects the machinability but not the combined carbon, while oxygen from blast moisture affects both combined carbon and machinability and the oxygen carbon ratio of the air blast and the coke do not affect either combined carbon or machinability, while, further, the ratio of moisture to air in the blast is more effective in determining the quality of the resulting iron than the ratio of moisture to iron. These statements are not to be construed as contradictions of the author's findings but only as evidence of the extremely complicated condition which must exist to account for all of them. Perhaps we must consider the matter from the viewpoint of the equilibrium between H and O at high temperatures. Under such conditions, it is as Boegehold himself points out, extremely difficult to analyze separately the effects of each variable and that our best hope is that a few variables will each produce such radical effects as not to escape notice.

A means of clarifying the situation might perhaps be found in the following expedient. Assume that for the range of values involved the physical properties measured are linear functions of free and combined carbon. Then any constant measured, called P will be

$$P = x + y \text{ z Comb.C.} + z \times \text{Graph. C.}$$

From the available and numerous observations, calculate x , y , and z by the usual processes of the method of least squares.

Compute the algebraic differences between the observed values of the constant P and that calculated from the equation. Plot these differences against any variable suspected of causing them and observe whether a relationship apparently exists. If so, compute the appropriate coefficient and introduce it into the above formula with an appropriate change in x and again compute the value of P to be expected from the observed values of combined and graphitic carbon and of the other variable just introduced and proceed as before. In this way it should be fairly easy to determine which of the many variables recorded actually independently affect the property under observation. Such a procedure, being entirely impersonal, obviates the possibility of unconsciously selecting some variables for undue importance or slighting another due to the observer's former experience and hence possible prejudices.

The writer again repeats, in closing, that he does not assert that such errors exist in the paper under discussion but wishes merely to make constructive suggestions as to a fairly accurate means of evaluating so complex a mass of data as here submitted by the original author.

A. L. BOEGEHOLD: In view of Mr. Schwartz' comments on the lack of information in this paper as to the relation between combined carbon and the various physical properties listed on page 96, the author admits he should have been more explicit in the paragraph at the bottom of page 125, where it is stated that "curves were plotted between test results and values for operating circumstances which seemed as though they should be related and also between values which seemed to have no relation." This statement should have been supplemented with the information that attempts were made to show a relation between combined carbon and practically every physical property studied but no apparent relations could be found except those which are given in the paper. Apparently the influence of combined carbon upon these physical properties is no stronger than that of a good many other factors which vary somewhat in spite of us. The point we wish to drive home in this paper is that certain factors influencing the quality of cast iron are outstanding and overshadow the effect of other factors usually considered as important. Until we can hold such outstanding factors constant, it is impossible to determine the true influence of other factors, such as combined carbon, etc.

With regard to the comments on results obtained with the dilatometer, the author agrees that it is entirely possible that the shape of the dilation curve in passing through the critical ranges might be ex-

plained by studying the changes in combined carbon. It was not the purpose of the investigation, however, to go into this detail. The dilatometric study was used simply to show the similarity between pig iron and cast iron made from that pig iron. The mechanism responsible for the amount of change in passing through the critical temperatures would have to be a subject for a separate investigation.

It is true, as Mr. Schwartz says, that without the assumptions as to the effect of blast furnace travel upon machinability there would be absolutely no relation between blast moisture and machinability and this curve would not have been included if we could not have shown that the points lying outside of the two straight lines represented irons made from pig iron produced in abnormally slow or fast traveling furnaces.

The inference which has been drawn by Mr. Schwartz that oxygen from the blast moisture affects both combined carbon and machinability was not intended by the author. It had not occurred to him that the oxygen obtained by the dissociation of water would be considered as behaving any differently than the oxygen going into the blast furnace in the air. It was the author's impression that any effects produced by moisture in the blast must necessarily have been tied up in some way with the hydrogen resulting from dissociation of the water, rather than from the oxygen. However, the behavior of oxygen just released from combustion with hydrogen may differ from that of oxygen brought in by air.

As was stated in the paper, and as Mr. Schwartz admits, it is extremely difficult to draw conclusions from such a complicated mass of data, and the author believes that any further clarifying of the situation must be done in further investigations wherein the blast furnace operations are held more uniform through controlling coke quality and therefore rate of furnace travel and in drying the blast to a constant quantity, in order that there will be fewer variables affecting our final cast iron product, rather than by further juggling of the data obtained in this investigation.

WRITTEN DISCUSSION—SUBMITTED BY J. L. HEFFRON*

The data accumulated in this article are very interesting and show how extensively this question of blast furnace operation, and the pig iron it produces, has been a problem for all foundries. Ours has been no exception and we have gone through this trouble of internal shrinkage, draws, cracks, hard castings, etc. While we are not getting one hundred per cent results we have made some observations that have warranted a change in material and practice to improve our final castings considerably.

We started our investigation at the cupola and worked backwards to the blast furnace, so I would like to bring up a few points, for written discussion, starting with the cupola practice used for conducting these tests.

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Coke, being the first material charged into the cupola, should be our first for consideration. I might add here that the development of the test for the combustibility of coke, as given in the appendix of this article, is a test that can be used to great advantage by both foundrymen and blast furnace operators. It would have been interesting if the analysis of the various cokes as tested for their combustibility (Fig. 2) had been given, such as the comparison of the apparent specific gravity and volatile matter between coke No. 1 and No. 6. These physical and chemical properties control the burning rate of coke. If the volatile matter is low it's a good indication that the proper coals have been used for coking and that it has received the right number of hours to produce a good metallurgical coke. The apparent specific gravity is the proof.

I would classify the cokes from by-product ovens as follows:

- First—*Domestic*—Usually discharged from the oven as soon as the by-products have been removed from the coal.
- Second—*Blast Furnaces*—Coke allowed to remain in the ovens a few hours longer than domestic, but not long enough to make it too dense in structure (fast burning coke).
- Third—*Foundry Coke*—Coal coked for ten or fifteen hours after the by-products have been removed giving a dense hard coke (slow burning).

Refer back to the specifications of the cokes used for these tests as given on page ninety-six, article (b); "(b) Coke—Burning rate to be less than 3.5 minutes for 250°F. temp. rise and minimum temp. rise of 270°F." It was our experience that fast burning coke in the cupola was causing a lot of our trouble for the following reasons:

- First—Structure, being too open and weak—it would break up under successive burden charges. When loaded to the charging doors and the blast started this coke would "set" from eight to ten inches resulting in a low bed giving cold and oxidized iron.
- Second—A fast burning coke is readily acted upon by carbon dioxide and converted to carbon monoxide, a condition desirable in the blast furnace, but not in the cupola. This cold metal is also readily acted upon by the water vapor in the blast.

An oxidized iron is the foundation of more metal trouble in the foundry than any other cause known, such as, raising the temperature at which the metal usually sets, which shortens the life of the metal, prevents proper feeding and results in internal shrinkage. This high temperature at which oxidized metal sets also increases the amount of combined carbon resulting in draws and cracks in small size castings.

On the other hand a slow burning coke with high apparent specific gravity and low volatile matter will have a dense hard structure capable of holding the coke bed at the proper height above the tuyeres. This coke should be uniform in size for an even distribution of the air.

With coke of this nature it is necessary to regulate the blast pressure accordingly. We found that a low pressure worked best, that is, a pressure

of enough ounces to prevent the air from going up the sides of the cupola. With a slow burning coke the conversion of CO_2 to CO is much slower with a low pressure. With this slow reaction, and a bed coke of the proper height, you get the maximum amount of CO_2 , or the hottest zone just under the metal on top of the coke bed. If the proper ratio of coke to iron is used to maintain this zone of combustion it should not be affected by the water vapor in the air under normal conditions.

This question of coke is by no means a cure all for shrinkage, draws, hard spots, etc., but it is a good point from which the foundryman may start checking up his operation.

This brings us to the question of blast furnace operation and pig iron. Here a fast burning coke is desirable as the carbon monoxide is wanted for reducing the iron. This has been very well brought out in this paper. I also believe that the blast furnace operator should use enough coke for insurance against the refrigerating effect of the moisture in the air.

After we had regulated our coke we occasionally ran in to internal shrinkage, draws, cracks, etc., in our small size castings and upon checking over our pig iron we found this condition in the castings occurred when we used a pig iron of very poor physical appearance, that is, pig iron that had deep pitted chilled surfaces, slag and dross on the top surface and flaky oxidized iron and "shot" throughout the upper half of the pig.

We were not sure that pig iron in this condition was causing any of our trouble. The blast furnace people took the stand that pig iron was pig iron and that it had to be right. If it was not right the furnace would not operate correctly, that is, the metal would not be up to temperature, the slag would be off, they would not produce their normal tonnage, etc.

Still our trouble always returned when we used pig iron showing these defects until finally we stopped all coke made pig iron and ran for several days with charcoal pig iron, or until our sprues as returned to the cupola were free from all previously used coke iron. When this was accomplished we started using coke iron again that was free from all of these physical defects. The physical appearance of the pig iron is, in my opinion, our "yard-stick with which to determine whether a pig iron will or will not cause certain defects in our castings."

We discovered in our cupola practice if we poured a ladle of oxidized metal into small size castings that these castings showed all the ill effects of high combined carbon, gas holes, etc. If virgin iron in this same condition from the blast furnace is poured *directly* from the furnace into a casting machine and water quenched, the chemical composition is not necessarily affected, but the structural composition is very much off from normal iron. If this "raw" or "unfinished" iron is poured into wet or damp lime coated molds causing more "boiling" of the metal and if it has not been properly skimmed at the casting machine allowing the slag, dross and other impurities to mix with the metal, the physical and structural composition is further upset.

As the cupola is simply a liquifying operation and does not reach a temperature high enough for any refining of the metal, this pig iron has a tendency to revert back to this condition on solidifying in the casting (as referred to in article one, page 146) causing internal shrinkage, draws, etc. When pig iron of this nature is used with poor coke and careless cupola practice the results can not help but be disastrous.

In my opinion it's just a matter of good practice on the part of the blast furnace men, producing merchant iron, to avoid these conditions. The author is right in his assumption that iron has to be right or he will know it from the way his furnace is operating. The average blast furnace superintendent is a man that has spent several years around a blast furnace and he can come pretty near telling what it is going to produce by the way it is working.

I also believe the operators are beginning to realize that it is possible to spoil or ruin good pig iron in the casting machine for reasons stated above, while, on the other hand, properly reduced iron can be made suitable for the foundryman with somewhat of the following treatment:

First—The entire cast from the blast furnace is caught in one large open top ladle, sprinkled with cinders, and allowed to "cure" by standing for approximately one hour before casting in the machine.

Second—Ahead of the casting machine is a properly constructed "runner box" or trough. This runner box has a trough for running off the excessive slag, dross, etc., with the assistance of a man always on hand. When the runner box is filled, the gate is opened up allowing nothing but clean metal into the casting machine molds.

Third—The lime spraying machine is situated in such a location that the lime is sprayed on the molds at just the right temperature so that the molds are perfectly dry when the metal enters them. In this way the metal stays quiet in the molds and is partly solidified, on the top surface, when the water strikes them.

A. L. BOEGEHOLD: The point concerning the relation between volatile matter, apparent specific gravity and burning rate is one that we have paid considerable attention to. That relation was one of the first things we tried to establish in our study of coke which included over one hundred samples of foundry coke. We have been unable to find any relation between burning rate and per cent cell space, apparent specific gravity, volatile matter or per cent fixed carbon.

This sort of practice gives a clean and solid casting with well distributed graphite and should be capable of carrying a large percentage of scrap in the cupola.

If the foundryman will include a physical specification, along with his chemical, to cover the appearance of his pig iron, and, check over his coke and cupola operation, he should go a long ways towards cleaning up some of his metal problems.

WRITTEN DISCUSSION—SUBMITTED BY R. S. McCaffery*

Any attempt to obtain information to correlate the influence of blast furnace practice on the quality of pig iron and to compare this with the qualities of cast iron made by re-melting the pig iron in a cupola furnace, must be of great interest to both the producers of pig iron and the makers of cast iron castings.

The material for such a study will require that information be obtained concerning a large number of factors or essential elements, each of which is changing as conditions change, and for the most of these factors or essential elements, it is not even known how rapidly these changes do take place. For this reason, the amount of data required to permit the correct solution of the problem will be very large, and of necessity the study of the data will take a very long time.

In making such a study, it will be necessary—

- (a) To collect adequate blast furnace data,
- (b) To analyze these blast furnace data and to draw conclusions from them,
- (c) To conduct the foundry experimental work and to analyze its data and
- (d) To correlate the analyzed data of (b) + (c) above.

The collection of all the blast furnace data necessary will be difficult in so much that all the factors or essential elements entering the problem must be given representation in it. This will involve considerably more work than the mere copying of the daily reports furnished by the blast furnaces.

The analysis of these data, assuming they have all been obtained, will be even a more difficult thing to do, and it will require real understanding of the blast furnace processes and the exercise of great discrimination when making comparisons of operations under such widely varying conditions.

Finally, the bearing of these blast furnace data on the experimental results which have been rigidly scrutinized will then have to be weighed, and logical and correct conclusions drawn therefrom.

The paper under discussion would have been most welcome, had it satisfied these general specifications. As, in the opinion of the speaker, however, it does not do this, he very reluctantly feels bound to point out the places where, in his opinion, the data seems incomplete and the interpretation of the data erroneous.

On page 95 is a sample Blast Furnace Data Sheet. This lacks, among other things, any information about the chemical analyses of the constituents of the furnace burden or of the physical conditions or size of the ore lumps that affect reduction. There is nothing to indicate if items 4 to 17, inclusive, and 24 to 26, inclusive, were kept constant during any time, or, if they varied, at what rate they did vary.

There is no information on this data sheet, either, as to the period of time that is represented by the data—whether it was for a shift, or a

*Professor of Metallurgy, University of Wisconsin, Madison, Wis.

day, or a week; nor is there any information as to how the data on the sheet are to be applied to a single cast; nor any information regarding the changes in operating conditions in the blast furnace for the time prior and subsequent to the cast.

For these reasons, the speaker believes the data on blast furnace operation to be absolutely inadequate to furnish a basis on which to proceed to correct interpretation.

In addition to the inadequacy of the blast furnace data, the speaker believes the author's interpretation of it to be wrong. For example, on page 100, the author states, "When we take into consideration the height of the furnace in determining the relative time that any particle of ore remains in the furnace, we find that each particle of burden remained in A furnace while making heat 2, two and sixteen hundredths (2.16) times as long as the burden remained in D furnace while making heat 7." In the above calculation, the author uses the largest diameter of the furnace (the diameter at the top of the bosh), and he obtains, therefore, minimum velocities. These furnish no proof of the correctness of his conclusions, and the chances are decidedly that it is wrong. Why, if there were two blast furnaces exactly alike in every respect except that one had a larger diameter at the top of the bosh than the other had, and both charged at exactly the same uniform rate and both producing at the same uniform rate, the author would have us believe that a particle of ore took a longer time to pass down the length of the wider bosh furnace, whereas a particle would take the same time in each (except for small differences in internal friction). The same mistake is made when discussing combustibility of the coke in the third paragraph on page 102. As a matter of fact, coke is burned in the hearth of the blast furnace, and not at the top of the bosh where there is very little activity. Similar mistakes are made in Fig. 12 with the "Relative Rate of Production of Pig Iron," and also in the argument of the author on the same general subject, pages 129, 130, and 131. In the author's argument, page 102, he makes use of such data, and he would have us believe that in the case of my two identical furnaces (identical except for diameter at the top of the bosh), both operating with the same regular charging and same regular rate of production, that the narrow bosh furnace was driving faster than the wider bosh one—whereas they are both operating at the same rate.

Then, too, in Table 1, page 98, furnaces are compared on the basis of pounds of coke per ton of iron, while no information is given of the amount of iron in the ores or sinter, and without applying any allowance for the scrap on the charge. We are not even told how the quantity of coke was obtained that was used in this comparison between furnaces that is made in Table 1 on the pounds of coke per ton of iron, and it is very necessary to know how the figure used in the table was obtained. For example, in some plants, coke is actually weighed; others figure by volume and the daily figure is only relative, the actual figure being computed over periods from a week to a month; and some plants deduct from the weight of coke charged everything over an established moisture

figure; and still some others deduct the coke breeze, while some do neither.

The fourth step in an investigation of this sort is the correct analysis, correlation and interpretation of the data that were obtained. Figure 10, page 127, will illustrate mistakes in doing this. If there is any object in plotting this kind of data, it can only be to compare some inherent property of cast iron with some blast furnace factor. The property compared

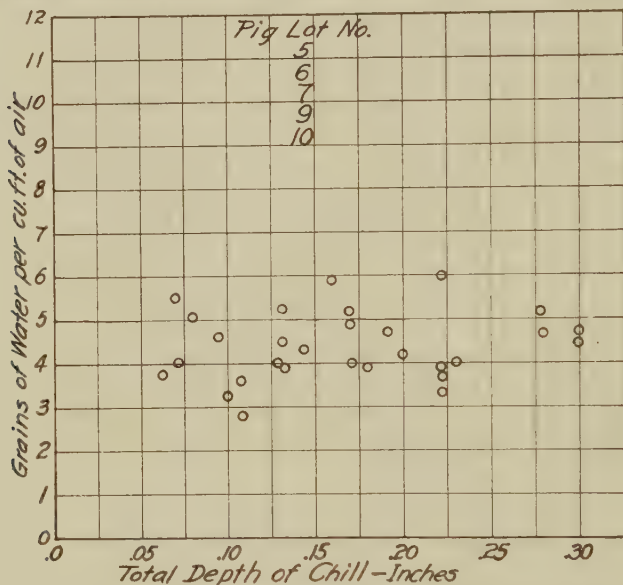


FIG. 1—RELATION BETWEEN DEPTH OF CHILL AND HUMIDITY OF BLAST.

must be one common to all irons, but perhaps varying in degree with each. If there is some iron of which it is not true, then certainly it cannot be a property that is common to all iron. If now we take the author's own data reported in Fig. 10, and if we make a diagram on the same scale that he uses, plotting his results from the greater number of his pig iron lots (see Fig. 1 of this discussion), a result is obtained that shows, if it shows anything, a horizontal tendency. This means that in over half of the pig iron lots with which the author of the paper experimented, there is absolutely no relation, as he claims, between blast moisture and chill, and Fig. 10 is worthless as representing any such correlation. Similarly, if we re-plot the author's data in Fig. 14 for the greater part of his pig iron lots, the only tendency that is indicated (see Fig. 2 of this discussion) is that machinability is not affected in any way by blast moisture. Again, if from Fig. 20 we re-plot the greater part of the author's data, these show no tendency to be anything but horizontal (see Fig. 3 of this discussion), thus indicating that there is no relation

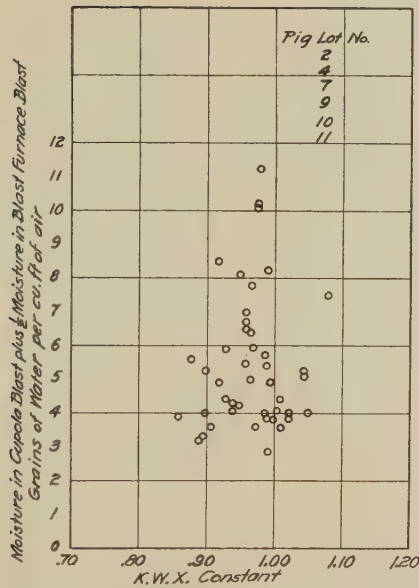


FIG. 2—MACHINABILITY AS AFFECTED BY MOISTURE IN BLAST

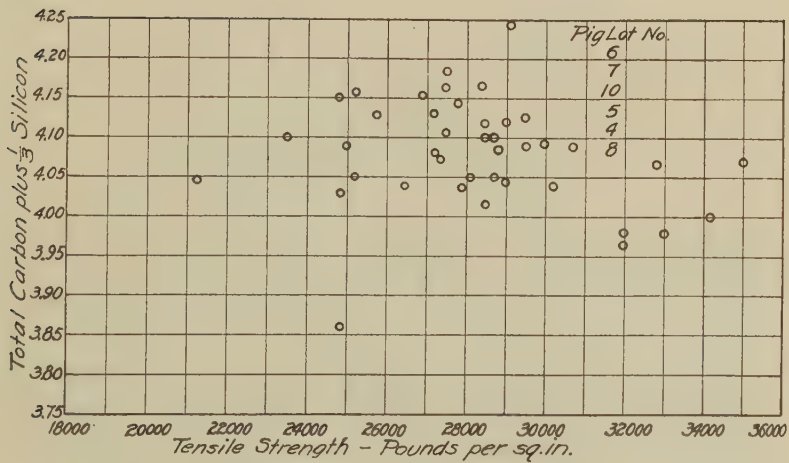


FIG. 3—EFFECT OF TOTAL CARBON AND SILICON ON TENSILE STRENGTH

whatever between total carbon plus silicon and tensile strength, as the author claims. And just once more—if the author's data in Fig. 21 are re-plotted, using again the majority of his pig iron lots (see my Fig. 4)—then there is no tendency whatever toward anything but verticality and no relation, as claimed by the author, between total carbon plus silicon and rigidity is indicated. The graphs of Figs. 10, 14, 20, and 21, therefore, do not represent any general inherent property of cast iron, and are valueless.

In three figures, Nos. 10, 11, and 14, the author uses in his comparison with other properties, the moisture in cupola blast plus $\frac{1}{2}$ moisture

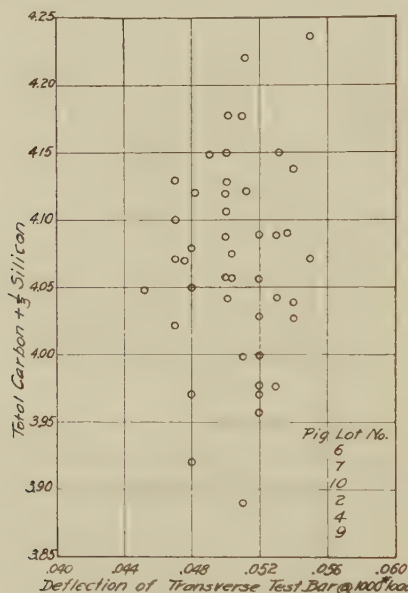


FIG. 4—RELATION BETWEEN RIGIDITY AND
TOTAL CARBON + $\frac{1}{2}$ SILICON

in the blast furnace blast. We are not informed as to whether or not the blast furnace operators compensated the blast temperature for the moisture variation. Then, too, in the argument at the bottom of page 126 to justify the addition of 50 per cent of the blast furnace moisture, it is stated the 50 per cent is to be added because there is 50 per cent pig on the cupola charge, and it is to be noted that not 49 per cent or not 51 per cent is to be added, but 50 per cent is the correct figure. But just observe here that with the 113 pounds of seven per cent silicon iron that is on the cupola charge, the author does not take any account whatever, to any per cent whatever, of the moisture in the blast when the silvery iron was made, and he totally ignores the moisture of the cupola blast on the re-melt of 250 pounds of gates and sprues. Neither

does he mention any place in the paper, the variation in composition of the 137 pounds of scrap steel charged.

Why is it, too, that in Fig. 12, the graph is drawn by using the average of each pig iron lot. In Figs. 10, 11, 14, 20 and 21 the data for the individual tests are reported but they are averaged in the case of Fig. 12.

There is no information given in the paper as to the reason all the tests of the various types employed were not reported in all the pig iron lots. Counting the number of tests in each pig iron lot reported in the graphs, a great difference in the number reported per lot was observed. These numbers per lot are shown in Table 1 of this discussion. For example, in Lot 1, from which there were four cast heats made, why is it necessary to make six tests to attempt to show machinability is affected by blast moisture, and four tests in the moisture chill comparison; whereas in Lot 11, where six cast heats were made, only three tests

Table 1

NUMBER OF TESTS PER PIG IRON LOT REPORTED IN FOUR GRAPHS

	Pig Iron Lot Numbers										
	1	2	3	4	5	6	7	8	9	10	11
No. Cast Iron Heats (Table 4, p. 136)	4	9	5	10	8	7	8	7	9	8	6
Relat'n between blast moisture and chill (Fig. 10)	4	9	9	5	5	7	7	6	4	5	7
Relat'n between blast moisture and comb'd carbon (Fig. 11) ..	4	10	9	6	5	8	10	5	4	6	9
Machinability as affected by moisture (Fig. 14)	6	9	9	5	5	8	9	5	7	11	3
Combined C + Si to tensile strength (Fig. 20)	5	6	9	8	2	8	7	5	8	11	8
Combined C + Si to rigidity (Fig. 21)	4	7	10	6	5	4	7	9	6	8	6

are reported for the first relation and seven for the second. Again, when in the reported relation of combined carbon plus $\frac{1}{3}$ silicon to tensile strength, why are only two tests on eight cast heats for Lot 5 given, when for the same number of cast heats in Lot 7, seven of these tests are reported? What is the explanation that all the tests were not reported?

For the above reasons, under each of the original specifications, the speaker believes that the inferences and conclusions drawn on page 146 have no warrant by any fact or facts proven in the investigation.

A. L. BOEGEHOLD: Mr. McCaffery devotes the first part of his discussion to the idea of what is required to solve the riddle of the blast furnace and makes the accusation that such a program has not been followed. There is nothing in the paper which justifies his assumption that our aim was to explain everything about the operation of a blast furnace.

The number of variables in blast furnace operation is so great that the possible combinations of conditions approach infinity, therefore, obviously any investigation measured in terms of years even can do no more than scratch the surface. The intention of this paper was merely to point out some of the *major* variations in blast furnace practice, the *major* variations in character of pig irons, and show that the character

of pig iron persists through cupola melting and show some of the variations in properties of cast irons of like chemical analysis.

Regarding criticism of Sample Data Sheet on page 95, which points out lack of information about chemical analyses of the constituents of the burden, the discussor must have known we had that data in order to calculate amount of slag per ton of iron produced.

The variation of items 4 to 17 is recorded on the various charts and blast furnace logs such as is kept by every blast furnace plant, and samples of which we had obtained for each cast in question. These are available for whatever study one desires to make.

As to items 24 to 26, does the blast furnace operator change his coke each hour of the twenty-four for variation in humidity?

The information collected was during periods of time when the data had any relation to the cast in question. For example, the coke and burden charged was obtained for the 24 hour period previous to and during the 24 hour period in which the cast occurred. The charts for blast temperature, pressure, etc., were obtained only for the 4 to 5 hours previous to the cast.

After all, the point we are trying to show about these various casts of pig iron is that they are made under different circumstances. We might have collected every conceivable kind of information about each of these casts, even what kind of sand was used in the troughs leading to the ladle, the analysis of the refractory in the ladle, etc., but no amount of additional data would add one iota to the data already given in showing that the pig irons were of different history. For these reasons the discussor's remarks are considered as entirely irrelevant.

He takes exception to the method of comparing rate of furnace travel. His illustration citing two furnaces equal in every respect, except the diameter at the top of the bosh, proves nothing so far as the furnaces under consideration in this paper are concerned. Does he mean to convey the idea that the rate of travel of ore through different furnaces does not vary between wide limits?

The unit of comparison selected to compare the operation of the seven different furnaces, namely, one square foot area at the plane of maximum furnace diameter, serves to show the large differences in quantities of material passing per unit time through the furnace. Computation of these quantities referred to one square foot area at the plane of the furnace hearth or in front of the tuyeres would show a similar variation in rate of furnace travel except that the quantities of material per square foot of area would be increased. A comparison on this basis would not in any way affect the pounds of air per pound of iron produced, or pounds of air per pound of coke burned, etc.

The discussor has made some surprising statements. He infers that reference has been made in the paper to the coke as burning at the top of the bosh. If he will read the paper more carefully, he will realize that such a statement is made nowhere in any shape or form. If I should

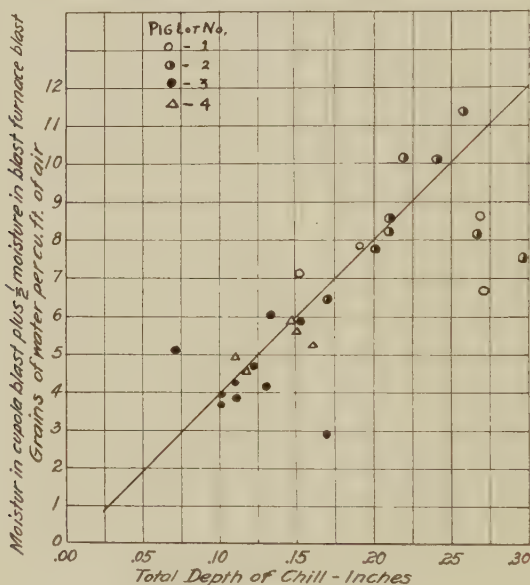
choose to express pounds of coke burned per square foot area at the stock line, does that mean that I think the coke burns at the stock line? His statement that there is very little activity at the top of the bosh is far from being accurate. If he were in there he might get a new conception of what activity there was. J. M. Camp and C. B. Francis in their book, "The Making, Shaping and Treating of Steel," give the temperature at the top of the bosh as 2,550 degrees Fahr.

He adheres to the idea that rating of furnace travel by means of reference to the maximum diameter renders Figure 12 of no value.

The discussor would have us believe that the top of the bosh is not a satisfactory reference point for comparing the performance of various furnaces. As a matter of fact consideration of some of the fundamentals of blast furnace behavior would show that no other reference point is permissible and that reference to rate of burden or coke travel at the hearth or tuyere level can be made only with total disregard for known facts. In the first place, the descending burden and coke in the blast furnace is gradually heating up and therefore expanding. In addition carbon dust is being precipitated from CO_2 when some reduced iron is reoxidized. Therefore by the time the burden has reached the top of the cylindrical part of the furnace, it has probably expanded enough or more than enough to compensate for the increase in diameter at that point and as a result the burden travel instead of slowing down might actually speed up. In the case of Mr. McCaffery's two blast furnaces alike except that one has a larger diameter at the bosh, he says the burden in the larger boshed furnace will travel slower. As a matter of fact, that larger boshed furnace charged with a particular kind of ore will travel faster at the bosh than the small boshed furnace due to excessive swelling of that particular ore by carbon deposition.

Now consider what happens at the point where the sides of the furnace begin to slope in, where the temperature is about 2,600 degrees Fahr. The iron sponge carburized to a certain extent begins to melt and runs between the coke lumps, greatly reducing the volume of solids; further down the coke is being burned to gas, reducing still more the volume of solids so that even though the furnace diameter is greatly reduced, the decrease in volume of solids is so great that the velocity of travel instead of increasing, slows down, becoming zero at a point slightly below the tuyere. Furthermore, all the impurities in the ore have been reduced to a viscous liquid before the tuyere level is reached; thus reducing the volume of solids to a greater extent. Since there is no burden at all at the hearth or tuyere level, what possible justification is there for rating burden travel with reference to that level? Furthermore, S. P. Kinney in Bureau of Mines Technical Paper No. 442, entitled "The Blast Furnace Stock Column," states that the reduction of 75.6 per cent of the iron ore takes place between a point near the top of the cylindrical portion of the furnace and the tuyeres. If this is so, then the rate of travel through this part of the furnace is the important factor and should be used in our comparisons.

Since the large diameter of the blast furnace at the top of the bosh is actually the smallest diameter in effect, it becomes the neck of the bottle and will control the speed of travel so that in the discussor's two blast furnaces equal in dimensions except in diameter at the top of the bosh, the narrow bosh furnace will travel faster at least through the cylindrical part of the furnace, if they both produce the same amount of iron. As a matter of fact, in order for two such furnaces to produce iron at the same rate from the same kind of burden, it will be necessary to alter some phases of the operation to get the burden to pass through the restricted zone fast enough to give production equal to the wide boshed furnace. The natural tendency in the narrow boshed furnace, all other things being equal, would



one furnace. Such a selection plotted in Fig. 1, page 698, plainly supports the idea that depth of chill is dependent upon humidity of the blast. The heats of cast iron represented in this graph were made from Lots 1, 2, 3 and 4 Pig Irons, which were all made in the same blast furnace.

It was specifically stated in the paper that a great many attempts were made to show relations between various factors and results by plotting the data. The majority of these graphs showed no relation whatsoever. In view of the complexity and large number of factors influencing the properties obtained in the cast irons, it was considered desirable to present graphs even if they showed only a trend. To any one familiar with the nature of cast iron and pig iron it is obvious that we cannot expect to obtain graphs with all points lying on a straight line, which leaves no question as to the relation.

The data were presented in the graphs in the manner which showed best the point intended to demonstrate. In the case of Figure 12 it was considered that an average of the points showed the relation to better advantage.

Regarding discrepancies in number of points in the different charts, there are several reasons. First: Runouts and other accidents sometimes occur in pouring test bars. Each test has its own particular test bar so that if in pouring a bar some accident occurs it means that we lose the data on that bar.

Second: In the original plotting of these curves, the points were marked with reference to our original numbers for the pig iron lots, which were numbers 33, 35, 38, 42, 44, 46, 48, 49, 50, 52 and 53. For the purpose of publication these curves were all replotted, using numbers 1 to 11 for the pig lot numbers. In making up Table 4 which gives the number of heats cast with each lot of pig iron, the new lot numbers were not applied correctly so that the number of heats cast, as shown by Table 4, page 136, is in error and does not check with the number of points in the graphs. After correcting Table 4 there were still a few points missing which have been supplied from the original data. The number of points missing, however, was not as great as indicated by Professor McCaffery's Table A, in which he reports twelve points less than are actually present in the graphs he refers to.

Third: Blueprints of these graphs supplied with the manuscript were used by the editors of the paper for replotting in such shape as demanded for printing the paper. Due to a similarity of some of the symbols, apparently their identity has been mistaken in replotting. This accounts for several discrepancies. Since the time available for getting the data ready for publication was short, and since the graphs in the paper appeared on casual inspection to agree with the original data, it was not deemed necessary to resort to the laborious and meticulous checking of these points for which we are indebted to Professor McCaffery. The change in Table 4 to bring the graphs in agreement with the number of heats cast from each pig iron makes no change in the arrangement of the points nor in the conclusions to be drawn therefrom.

WRITTEN DISCUSSION SUBMITTED BY R. M. ALLEN*

Both the author and the company sponsoring the work in connection with this admirable paper are to be congratulated on their achievement. It is a decided contribution to our knowledge of cast iron and, if accepted by blast furnace and cupola operators alike and attempts made to profit thereby, the results cannot be other than beneficial to the cast iron industry.

With each of the conclusions reached by the author, I am in hearty agreement,—in the case of some of them because no other conclusions are possible after a careful study of the voluminous data which have been obtained; in the case of others because they verify results of experimental work which I have been carrying on during the past two years for the American Car and Foundry Company.

While the bare statement of the results of Mr. Boegehold's work should be sufficient to form a working basis on which foundry operators may proceed and secure results, in the very nature of the case, in connection with a work of this type, there is always something unsatisfactory to the metallurgist and the research worker, and from statements in various places in the paper, it is evident that the author himself is in agreement in this matter. In every conclusion there is hidden somewhere the little word, "Why?" and some of us will not be satisfied until we secure the answer. In some cases, it is only upon the answer that further work can be predicated. For instance, why does the variation in the moisture content, in both the blast furnace and cupola, have an effect on the resultant product when it is apparently not noticeable in the ultimate chemical composition. No one will believe that it is the presence of water, *per se*, that produces the effect, and the total percentage of water, when compared with the volume of the iron, is relatively small. We must look for the answer to this question in the results of the disassociation of water at this high temperature in the presence of carbon. Probably the result is due to the presence of nascent hydrogen or oxygen. The positive answer to this question might enable us to vary, to a considerable extent, the characteristics of the iron by a definite control of the humidity or moisture content, or by the use of some other material which would supply the nascent element.

The various graphs given by Mr. Boegehold, and which in every case show the results as bands of appreciable width rather than as narrow lines, indicate variations which are obviously outside the scope of his paper. The unfortunate situation, as regards the research study of cast iron, is that metallurgists in the past have been inclined to consider cast iron as a relatively simple subject and not worth serious consideration on their part. When it is realized that exactly the opposite is the case and that cast iron is probably the most diabolically complex of all metals with which we have to do, more attention will be paid to a careful study of it and improved irons of uniform quality will be produced.

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Some of the research work on cast iron which we have been carrying on has thrown additional light on some of the causes of the variations which are noted by Mr. Boegehold, and it might be of interest to pass them on, in a brief way at this time, as they help to prove the point which Mr. Boegehold is trying to make, that variations occurring over a considerable area still do not affect the conclusions which he has reached. The independent action of all of the various constituents of cast iron have been carefully determined and form the subject of many technical articles and works on cast iron, but there is not sufficient stress placed upon the interaction effect of the various components in the presence of other elements; for instance, the softening effect of silicon is modified to a noticeable extent by slight changes in the manganese content, but the effect of the manganese itself is varied considerably by very minute variations in the sulphur content. The effect of all three of these elements, in turn, is modified by the phosphorus content, and it is the operation of all of these elements together, interacting with the total carbon, that determines the final characteristics of the iron. As to whether or not variations in the percentage of these elements, including carbon, have any appreciable effect on the emissivity of the iron, would form an interesting subject for research, as any variation in the emissivity would have an effect upon the rate of cooling. Very slight variations in the molding sand, whether dry or green, have appreciable effects upon the resultant iron, especially when the iron is being cast into test pieces, and so we might take up each variable and attempt to show why certain results are obtained.

With especial reference to the main object of Mr. Boegehold's paper; i. e., the demonstration that characteristics of the pig iron are transmitted to the finished product, our work has shown that this is not only true of pig iron but is also true of any scrap iron that is used in the cupola. It would almost appear that there is a Mendelian law which operates in cast iron metallurgy as well as in biology. One simple, yet rather spectacular proof might be cited. Chill pieces were taken from the tread of a mine car wheel and gray iron from the hub and spokes of the same wheel. These were melted in an Ajax-Northrup high frequency induction furnace, care being taken to prevent any oxidization of the silicon and carbon insofar as possible by excluding free access of air. When heated and poured into test bars under as nearly identical conditions as it was possible to secure, the bars which were made from the gray iron were perfectly gray, bars made from the chilled tread were white, and mixtures of the gray and chilled material were generally mottled. While the temperature to which the iron is subjected has some effect on this result, it is not possible to entirely eliminate the tendency of the material from the tread of the wheel to chill, even when heated to a temperature of 3000 degrees Fahr. Undoubtedly, there is a temperature which would entirely destroy this tendency, but it is very likely that under no condition would such a temperature be reached in the hottest part of a cupola. The answer to the question, "Why?" in this case, is rather too involved to present in a discussion of this paper, but it may be stated briefly that



FIG. 1
SLIDE 1—1000X

FIG. 2
SLIDE 2—2000X
COARSE PEARLITE

FIG. 3
SLIDE 3—2000X
FINE PEARLITE



FIG. 4

SLIDE 4—2000X
FINE GRAIN PEARLITE

FIG. 5

SLIDE 5—2000X
SPHEROIDIZED CEMENTITE

FIG. 6

SLIDE 6—2000X
PRIMITIVE GRAPHITE FORMATION

there is ample evidence that the crystalline aggregate nature of iron is not destroyed in ordinary remelting.

Mr. Boegehold has intimated the possibility of some of the effects being caused by the presence of other materials than those ordinarily recognized as being present, and mentions his attempt to isolate such, if present, by spectroscopic methods. While his results were negative, it still should be borne in mind that there are possibilities of the presence of extremely minute amounts of other elements affecting the crystalline habit of the iron and so modifying results. This is another subject for further research.

I have only one slight criticism of this entire paper, and that is his statement that no relation could be detected between the microstructures of pig iron and cast iron made from it. This is probably correct at the relatively low magnification ordinarily employed for the study of cast iron. My own work has convinced me, however, that differences or similarities between cast irons may be readily discerned by a critical study at high magnifications, i. e., the order of at least 3000 diameters.

In conclusion, I think it should be pointed out that in addition to the specific problem which Mr. Boegehold has solved and presented so admirably, there is information in his paper that ought to be utilized by progressive foundrymen even for cupola operation. I refer especially to the study of the combustibility of coke. The characteristics of the coke certainly have a bearing on cupola as well as blast furnace practice, and, if the utmost results are desired, all of these little points must be taken into consideration.

R. M. ALLEN: At the last minute, after I had written my discussion, I thought that it was not fair to Mr. Boegehold to criticise the one point that I did criticise—that is relative to the study of the microstructure of the irons involved—without bringing along some evidence to make my point more plain. I think that similarity in microstructures could have been stressed in his paper had Mr. Boegehold followed it up.

I believe that each one of these irons could be demonstrated to bear a relationship,—that is, the finished product to the iron in the pig,—by some characteristics which can be shown microscopically. I never yet have seen two irons which have different characteristics in which you cannot see a difference in the iron structures themselves, and when two of them are similar, generally you will find the cause of the similarity in the microstructure.

I brought along, therefore, a few lantern slides which show variations such as I have reference to. They are only illustrative of the point that I wanted to make, that is, that little details are disclosed in the high power study of cast iron that can emphasize or prove the point that there is a difference or similarity.

Slide 1 is of a relatively low power photomicrograph of a general field, the magnification being only 1000 diameters, but it shows the graphite flakes plainly with a rather coarse pearlitic structure, and clear areas of



FIG. 7
SLIDE 7-2000X
AUSTENITIC STRUCTURE

FIG. 8
SLIDE 8-2000X
EFFECT OF NICKEL AND CHROMIUM IN CAST IRON

ferrite. This is what you might call a picture of typical cast iron. The remaining slides will be at magnifications of 2000 or 3000 diameters, so the fields of view will be correspondingly restricted.

Slide 2 shows a very coarse pearlitic structure. There is only one graphite flake at the top. There is a little carbide, undissolved, over at the side, and very coarse pearlite all the way through, with considerable free ferrite.

Slide 3. Notice the difference in this slide. Here you see very fine graphite, considerable of it,—also a very fine pearlitic structure. Attention is called to the large pearlitic grain comprising nearly one-half of the picture area so as to contrast it with the grains of the next slide.

Slide 4. In this iron the grain structure is relatively small in contrast with the last. I have tried remelting these irons in the high frequency induction furnace to see whether or not these characteristics would persist, and I find that they do; when this iron is remelted, it will tend toward substantially the same structure.

Slide 5 is an iron that shows a spheroidized type of cementite in the pearlite. An interesting thing in this specimen (and this can be followed through many cast irons at high powers with very careful preparation of the specimens) is the dark area at one end of the small graphite flake. There is evidence here that the precipitation of the graphite is not complete, that is, it has yet to travel in and unite with the sharply defined graphite area. The next slide will illustrate this point further.

Slide 6 is an iron which shows the most primitive form of graphite distribution that I have ever seen. The dark areas show the beginning of precipitation of graphite, which, if it had had time to develop properly, would have segregated into larger, definitely defined areas.

Slide 7 shows an iron with a sorbitic structure instead of pearlitic. Under low magnification, you would not know whether this was pearlite or sorbite. While the sorbitic structure is undoubtedly the result of the manner of cooling, it appears that it can be induced much easier in some irons than in others.

Slide 8. In this case we have the indication of the effect of a small percentage of nickel and chromium in the iron. There is decided evidence of a sorbitic structure surrounding the cementite area. When nickel alone is present, it does not give this structure, as the nickel acts with the silicon to give increased graphite precipitation, but when you neutralize the effect of the nickel with chromium, then you get this structure, which is quite typical. In this slide there can be seen two small, sharply defined, angular crystals. Ordinarily you read about the manganese sulphide occurring as round globules, but when a specimen of cast iron is carefully prepared and studied under high powers, they are discovered to be, not globules, but sharply defined crystals.

Slide 9 illustrates the crystalline form of manganese sulphide; I am showing this photograph of a manganese sulphide crystal at a much higher magnification, 3000 diameters. The fact of its crystal form cannot



FIG. 9

SLIDE 9—3000X
MANGANESE SULPHIDE CRYSTAL IN CAST IRON

FIG. 10

SLIDE 10—2000X
BALLING UP OF SULPHIDE CRYSTALS IN CAST IRON



FIG. 11

SLIDE 11—2000X
CUBIC CRYSTALLOIDS IN CAST IRON

FIG. 12

SLIDE 12—3000X
CEMENTITE DISSOLVING TO FORM PEARLITE IN CAST IRON

be disputed. The way in which several manganese sulphide crystals sometimes ball up is characteristic of certain irons, as the next slide shows.

Slide 10 is an iron in which these manganese sulphide crystals are still angular, but they occur in groups instead of singly, and they are intergrown, quite characteristic of this particular iron.

Slide 11 is an iron which is characterized by the presence of small cubic crystals. They are out of focus because they are not attacked by the etching agent, hence stand up above the rest of the surface. Such little inclusions as these help to determine similarities or differences between cast irons when studied under high magnification.

Slide 12 is one that I added more because of general interest. It shows, at high magnification, cementite dissolving to form pearlite. Such a condition was very characteristic of this particular iron.

From these slides you will perhaps get the point I wanted to make in criticising Mr. Boegehold's paper, that if he had only had the time to have elaborated and studied these irons from this standpoint, I think he would have absolutely clinched his argument.

A. L. BOEGEHOLD: As Mr. Allen says, we did not have time to go into even anything higher than 100 diameters' magnification. I want to thank Mr. Allen very heartily for his excellent discussion. It certainly makes an addition to the data that I have presented.

WRITTEN DISCUSSION—SUBMITTED BY JOHN SHAW*

Mr. Boegehold's data from the blast furnace are fairly complete, but only for the particular time under notice. Even these figures might have been seriously influenced by some irregular working that had occurred just before. It is evident in the case quoted from the same furnace, 8E, 9E. No furnace manager can afford to throw away 6 cwts. of coke per ton of metal produced, as shown here. The same applies to many other irregularities, increase of smalls, less iron in the gangue, higher blast pressure because of the effect of smalls, etc. I hold no brief for the furnace manager. I have, after working in foundries near the blast furnace for fifteen years, an idea of his difficulties in producing a regular product, especially if he is making two or three brands of iron. If, in cupola practice, we have trouble in keeping a regular iron, how much more so where the raw material varies with every charge. While it is certain more careful furnace operation (this means extra cost) would yield a more uniform iron, some of the variations mentioned by Mr. Boegehold are unavoidable. One regrets that the author has not given as full data concerning the investigation while under his control. A full table giving analyses, tests, etc., such as was made out for the blast furnace return, would have been much more helpful than the graphs with their ever changing comparisons. I have spent quite a few hours studying these graphs, but must confess that I can arrive at no conclusions. Take the moisture question, from Figs. 10 and 11. You

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notice "grains of water per cubic foot of air", varies much more in the cupola than the blast furnace. Is the effect the same?

Table 1
GRAINS OF WATER PER CUBIC FOOT OF AIR

Iron	Furnace	Cupola Highest + $\frac{1}{2}$ Furnace	Cupola Alone	Cupola Lowest + $\frac{1}{2}$ Furnace	Cupola Alone
1	3.2 grs.	8.7 — 1.6 grs. =	7.1 grs.	6.7 — 1.6 grs. =	5.1 grs.
2	6.1 grs.	11.49 — 3.05 grs. =	8.35 grs.	6.5 — 3.05 grs. =	6.1 grs.
3	2.6 grs.	6.1 — 1.3 grs. =	4.8 grs.	2.9 — 1.3 grs. =	1.6 grs.
6	1.56 grs.	4.6 — 0.78 grs. =	3.82 grs.	3.6 — 0.78 grs. =	2.82 grs.

I have not checked all the others, but the examples before you (Table 1) show that in the cupola the grains of water vary from 1.6 to 8.5 grs. per cubic foot of air. If this is a vital factor, a table taken from the various graphs should show it. I can find no evidence to support the claim. At the same time, the methods of testing and the lack of vital information, such as analyses, micros, transverse tests, etc., make it impossible to come to any clear conclusions. I included No. 6 in the table because it has about the lowest water in the blast furnace and lowest average in the cupola. The combined carbon is most regular and the silicon only varies 0.06 per cent in the seven tests. Under these conditions you might expect equal results, but they vary quite as much as No. 2 with its large water content in both furnace and cupola, if you allow

for the higher total carbon + $\frac{\text{Si}}{3}$ of the latter.

Table 2

	Water		Chill, in Inches	Combined Carbon, Per Cent	Machining
	Max. Grs.	Min. Grs.			
No. 2.....	11.4	6.5	0.17 to 0.30	0.48	0.92 to 1.07
No. 6.....	4.6	3.6	0.08 to 0.28	0.36	0.84 to 1.07
	Tensile Strength,		Deflection, in Inches	Silicon Variation,	Per Cent
	Pounds Per Sq. In.				
No. 2.....	29,100 to 33,100		0.190		0.50
No. 6.....	24,700 to 35,000		0.177		0.06

How far these results are affected by wrong testing methods we do not know. The cupola conditions are anything but ideal for an investigation of this type. Much has been said of the influence of the coke. Even the test on page 96 would allow a fairly large variation over the 12 months, yet we are given no data on this question. The cupola charges of 1000 pounds made up of 75 per cent pig and scrap, 13.7 per cent steel, and 11.3 per cent of a 7 per cent silicon pig, when taken out in 500 pound ladles would lead to irregularities, especially if the steel varied much in size or the manganese in the silicious pig as it often does. A recent experiment illustrates this. It was carried out in a small cupola taking $2\frac{1}{4}$ cwts. charges. Through some misunderstanding five charges were put on instead of four. The ladle only held 10 cwts. Each charge contained steel. When 9 cwts. had been tapped, a chill test was taken which only

showed $\frac{1}{8}$ -inch deep instead of $1\frac{1}{4}$ -inches. Tapping another cwt., thus filling the ladle, the test showed a depth of $\frac{7}{8}$ -inch. The remaining cwt. tapped into a shank was white. The steel, although charged on the coke, was on the heavy side and there is no doubt we had the steel from at least two charges in the last ladle.

I would also like to suggest that the author, after satisfying himself that the volume of water in the blast and the type of coke vitally affected the metal, might have taken an iron that had not been seriously affected by these items, and by means of either a steam jet or water spray in his air line to demonstrate from the same pig iron the effect of increasing the water in the blast or coke outside the specification or both on the physical properties of the metal.

The dilation curves (Fig 13) are very instructive and do show that certain characteristics are transmitted from the pig iron to the remelted iron. Unfortunately there does not appear to be much evidence that this is due to either coke or water in blast. Take the four irons given in Table 3 of this discussion.

Table 3

No.	Lbs. Coke Per Ton	Coke Per Hour Per Sq. Ft. Area	Grs. Water Per Cubic Ft. Area	Lbs. Water Per Ton Iron Produced	Lbs. Blast Pressure	Per Cent All Mine Ore	Slag
3	1930	105.1	2.6	38.5	10.75	89.90	Basic
6	1845	111	1.56	22	16	85.79	Acid
7	1860	148	2.30	32	13	90.31	Acid
11	2000	84	1.3	23.8	13.50	88.90	Acid

Coming now to the physical tests. The chill test was not suitable for the high silicons and carbons used. If an iron block chill test were used, such as that in my paper (A. F. A. transactions, 1926, page 848), the results could have been measured in white iron. The combined carbon graph shows little variation, except such as could be accounted for by composition of the iron. There is no evidence that water in the blast affects combined carbon. The machining tests are open to doubt, being carried out on plates cast green sand $\frac{3}{8}$ -inch thick. The cooling effect would dominate the slight alterations in composition. Because there are no analyses given, the results given in Fig. 17 must be taken with reserve. The total carbon content would have an equal effect as the silicon alone, and the altered positions of such as No. 7 and 10 as the silicons increase, is no doubt due to this cause. One regrets that more care was not bestowed on the methods to obtain tensile results. To attempt to collect data from a $\frac{5}{8}$ -inch diameter bar cast on its flat in green sand is futile. On that size bar both composition and structure effects would be reduced by the quick cooling action. What little dirt or scum there is would collect on the top side of the bar. That alone would tend to give an oblique pull. A straight pull is very seldom obtained with a rough bar, and so the results can not be depended on. If the author will cast several bars with two flanges, say of $2\frac{1}{2}$ inches in diameter, at the roots of the center portion, face these flanges up,

leaving the remainder of the bar rough, fit a gauge between the flanges, place the bar in the tensile testing machine and try the gauge between the flanges at three points with every 10 cwt. added to the test load, he will see how little dependence can be placed on rough bars. In a recent case, at 4 tons, the gauge would not go in at one point. At the second it would admit a 7/1000 feeler, at the last point an 11/1000 feeler. True results can not be obtained under these conditions. Take some of the figures

from Fig. 11; No. 2 iron with total carbon $+\frac{\text{Si}}{3}=4.06$ per cent gave 33,100 pounds. The iron with total carbon $+\frac{\text{Si}}{3}=3.89$ per cent, gave 29,250 pounds. No. 3 and 7 in each case show a fall with lower carbon and silicon. Take No. 6, with total carbon $+\frac{\text{Si}}{3}=4.03$ per cent, the tensile shows 24,700 pounds. With total carbon $+\frac{\text{Si}}{3}=4.07$, the tensile is 35,000 pounds.

We are not given the most important test, viz., the transverse on the A. F. A. standard bar, but even these were cast green sand.

I received a list of analyses from a prominent foundry manager who has for the last year been carrying out a somewhat similar investigation, viz., the effect of increasing steel additions and also altered cupola conditions on the physical properties, the idea being to aim at a constant analysis. As steel was increased by additions of 12 per cent silicon pig to the charge and FeMn down the spout, bars were cast in duplicate $1\frac{1}{4}$ inches square and 14 inches long, under standard conditions. The bars were then machined to 1-inch square and tested transverse on 12-inch centers. Each half of the broken bar was then turned in the lathe to the B. E. S. A. standard, giving 0.564-inch in the center and tested for tensile. Each half was again placed in the lathe and turned, one to 0.5-inch diameter, the other to 0.22-inch diameter for the shear test. This ensured the same structure all through and a duplicate test. The following examples of his results are given in Table 4; two from the bottom of the table, two from the middle, and two from the top. The analyses do not vary more than the authors, yet the transverse is raised from 2490 lbs. to 3560 lbs., and the tensile from 9.82 tons to 17.65 tons.

Table 4

No.	Trans., Lbs.	Tensile, Tons	Total Carbon	Comb. Carbon	Sili- con	Manga- nese	Sul- phur	Phos- phorus	Shear, 0.50" Diam., Tons
1	2490	9.82	3.44	0.59	1.56	0.68	.110	0.64	16.85
51	2540	10.9	3.41	0.51	1.93	0.76	.103	0.58	18.2
23	2910	13.9	3.36	0.56	1.70	0.76	.110	0.80	20.4
44	2910	13.7	3.52	0.62	1.45	0.70	.110	0.44	20.4
5	3470	16.7	3.35	0.60	1.68	0.65	.117	0.56	18
11	3560	17.65	3.35	0.60	1.47	0.77	.117	0.51	25.8

These figures will cause thought to those who always wish to connect physical results and composition.

I am extremely sorry to have to take the position I have in respect to this very interesting and able paper. The time spent on it must have been enormous and it is a great pity that the essential tests at least were not made under conditions that could be at once accepted. No doubt Mr. Boegehold has a mine of information up his sleeve in regard to this investigation and if he can establish his points, I will take his castigation gladly.

A. L. BOEGEHOLD: Mr. Shaw's statement that more careful furnace operation to get more uniform iron means extra cost, is not necessarily true. I know that several blast furnace managers in this country can show that more careful furnace operation means less cost.

He asks whether the effect of moisture in the blast furnace air has the same effect as moisture in the cupola blast. Plotting depth of chill, or combined carbon versus moisture in the cupola blast suggests a trend or a relation. When a correction of each point by adding to it a value for moisture of blast furnace blast emphasizes such trend by making the points fall more closely within a definite band, I am persuaded to believe that the effect of moisture in the blast furnace and cupola blasts is the same.

Table 2 of Mr. Shaw's discussion is offered to show that properties of iron made from Lot 6 pig vary as much as those made from Lot 2 in spite of less water in the blast in the former. This might well be expected when consideration is given to the fact that Lot 6 pig was made in a fast traveling furnace and Lot 2 pig was made in a slow traveling furnace. The differences that might be expected due to difference in moisture in blast might well be offset and masked by this difference in rate of furnace travel in the manufacture of the two pig irons used for these cast irons.

As to the cupola conditions used for this test, it was explained in the paper that this investigation was intended to be run in a manner that would parallel ordinary production foundry conditions with the only difference that variables would be controlled as much as possible. The cupola conditions selected are those in every day use in our foundries. As to the coke, it was stated in the paper that every shipment of coke was required to conform to the requirements of our combustibility test, namely, a minimum temperature rise of 270 degrees Fahr. and a burning rate less than 3.5 minutes for a 250 degrees Fahr. temperature rise.

We have found by experience that this method of control gives us more uniform coke than any other method now known.

The question of introducing a spray of water in the blast was remarked upon by Mr. Watson in the oral discussion.

As to the reason why dilation curves of cast iron simulate those of the pig iron used to make it, I must profess ignorance.

Whether the shape of the dilation curve of cast iron can be altered by water in the blast or coke so that it does not resemble the curve of the pig iron is outside the scope of this investigation. The important

point demonstrated in this work is that character of pig iron does persist through cupola melting and is conferred upon the cast iron.

Mr. Shaw states that the chill test was not suitable but gives no reasons why. I have examined his method as referred to on page 848 of 1926 A. F. A. Proceedings and see no advantage to be gained by using it. He says the results could have been measured in white iron—our chill *was* measured in white iron. The depth of chill as referred to in this paper refers to the depth of white iron below the surface cast against the chill. Referring to the statement that the variation of combined carbon could be accounted for by the composition of the iron; we could not find any evidence that composition had anything to do with the amount of combined carbon. Plotting combined carbon versus various chemical constituents gives no relation whatever. As stated in the paper, the only relation that could be found was the one given, namely, combined carbon versus water in the blast. Mr. Shaw may not admit Fig. 11 as evidence that water in the blast affects combined carbon, but I consider it as evidence of such influence.

His statement that cooling effect would 'dominate slight alterations in composition is not correct. As all specimens were poured at the same temperature, the rate of cooling would be practically the same in all specimens.

Mr. Shaw says that the altered positions in Fig. 17 of curves for Lots 7 and 10 pig irons as silicons increase, is no doubt due to variation in total carbon. The carbon content of these irons does not support his contention.

I do not agree with Mr. Shaw's statement that composition and structure effects, in the case of the $\frac{5}{8}$ diameter tensile test bar, would be reduced by quick cooling action. Has he any evidence to prove the statement? I have not seen any. In the case of two steels, $\frac{5}{8}$ inch sections can be quenched in oil or water and still show definite differences which are characteristic of each steel. Why should character of cast iron then be obliterated by a much slower cooling rate which if applied to steel would practically be considered an anneal?

The transverse load results on the A. F. A. standard test bars were not given as they contained no useful information. For this particular investigation, then, we cannot regard that test bar of any particular importance.

I am glad Mr. Shaw included the evidence showing the wide difference in strengths in irons of similar analysis as that supports the data I give on page 142 in Table 5. Mr. Shaw's data show even greater variation, due possibly to changes in amounts of steel in the charge.

WRITTEN DISCUSSION—BY J. E. FLETCHER*

The subject matter of the paper is of the utmost importance and has been tackled by the author in a very suggestive manner, and agrees in the main with investigations I have been conducting in Great Britain.

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The mass of test figures which have been accumulating on this side during the last ten years confirm the statement that the chemical analysis of a casting made from remelted pig iron or mixtures containing pig iron is only remotely representative of the mechanical strength of the cast iron.

Table 3 in the paper indicates quite a remarkable series of pig irons of approximately the same chemical analysis, the mean analysis being represented as under:—

	Per Cent	Minus Per Cent	Plus Per Cent
Total carbon	3.85	0.25	0.17
Silicon	2.50	0.17	0.20
Manganese	0.77	0.16	0.20
Sulphur	0.041	0.02	0.03
Phosphorus	0.167	0.02	0.06

The variations from the mean, shown in columns 2 and 3, are very small and indicate blast furnace burdens of similar chemical composition. The pig irons produced are approximately eutectic in character. This can be seen from the constitutional analysis determined as shown below.

In this determination I have taken the silicon as being present as the silicide Fe_3Si_2 and the phosphorus as in the eutectic Steadite.

The iron and manganese balance, if combined with carbon in the iron carbon eutectic (Ledeburite) proportion gives the index to the eutectic character or deviation therefrom of the irons in the series.

CONSTITUTIONAL ANALYSIS (MEAN OF THE SERIES)

	Per Cent	Variations from the mean	
		Minus Per Cent	Plus Per Cent
Total carbon	3.85	0.25	0.17
Fe_3Si_2	10	0.68	0.80
Steadite	1.67	0.20	0.60
MnS	0.11	0.05	0.08
Balance Fe + Mn	84.37	0.69	0.73
Eutectic carbon	3.79	0.18	0.23

The eutectic carbon in the above is 3.79 per cent, indicating a primary eutectic content of 88.16 per cent.

The type of iron is therefore slightly hyper-eutectic, containing 0.06 per cent excess carbon beyond the eutectic requirements.

I have repeatedly found in British practice that whenever blast furnaces are producing irons of eutectic character, there is a tendency towards variation in the physical properties, the eutectic being very sensitive to temperature and oxidation influences.

I am personally of the opinion that the presence of fine and dusty material in the ore has a great deal to do with the inequalities in the physical properties of the pig iron produced, for, as Kinney, Royster and Joseph have shown, the rate of iron reduction in the outer half of the furnace area at the horizon of maximum reduction is much greater than in the inner half or core.

We have proved in a number of cases that the method of charging, percentage of fines, and the size of the coke very materially influence the

rate of reduction in the outer zone of the furnace area, especially in large furnaces where the blast pressure is high.

In the small slow-running British furnaces, working with cold or cool blast (below 300 degrees Cent.) and using lean ores, the total carbon content of the pig irons, containing 2.0 per cent to 2.5 per cent silicon and 0.3 to 0.5 per cent phosphorus, is often between 3.0 and 3.3 per cent, the iron being hypo-eutectic.

I have often pointed out that the pig irons from such furnaces are remarkably uniform in physical properties as they are remarkably free from the Bessemerizing action of the air in the tuyere zone, the oxidizing action there being increased when the blast is primarily pre-heated.

It is incontrovertible that the use of ores rich in iron content, especially when these are in a fine state of division, results in pig iron high in total carbon. A little consideration will show that in rapidly driven furnaces, where the bulk of the reduction occurs in the outer half of the furnace cross-sectional area, the tendency will be for hyper-eutectic iron to be produced in the inner half of the furnace, where the burden descends more slowly than in the outer half.

The iron produced in the outer half may also be primarily eutectic or hyper-eutectic in character, but owing to the gases passing through that zone some carbon may be lost, or carburization of the sponge iron may be hindered by the presence of CO_2 and free oxygen in the ascending gases.

The streams of metal flowing into the furnace hearth from the two zones must be different in character and it is really inconceivable that a homogenous molten mixture can leave the tap hole.

I quite agree with the author that uniform conditions with respect to coke and air supply are important but, with all the good intentions in the world on the part of the blast furnace man, the changing physical properties of the ore, climatic conditions and the shape of the blast furnace lining upset many hoped-for results.

The author has referred to the mechanism of the reaction by which silicon and other metalloids enter or leave the iron.

I think it must be agreed that neither silicon nor manganese become alloyed with the carburized sponge iron until the slags are formed and liquefied.

Silicon will not alloy readily with iron rich in carbon except at temperatures in excess of, say, 1400 degrees Cent., though manganese will alloy at much lower temperatures, being helped and not hindered by the presence of carbon.

There must be, therefore, two sets of conditions prevailing in a rapidly driven blast furnace; one in which hyper-eutectic iron alloyed with manganese and silicon in accordance with the hearth temperature is formed and the other in which the silicon and manganese contents are modified by the presence of hypo-eutectic iron.

High silicon hyper-eutectic iron has no structural stability and rapidly graphitizes just before, during, and immediately after solidification, the cooled structure having the micro-structures shown in Figs. 3a and 3b. (Lots 3, 6, 7, 8, 9 and 10.)

These two sets of photo-micrographs are very instructive and indicate, in irons 3, 6 and 7 particularly, the influence of super-cooling on the cast iron structure.

I thoroughly agree with the author that the characteristics of the pig irons used in a cupola mixture are reproduced in the remelted iron and have specially noticed this in the case of mixtures containing steel scrap and pig iron of high total carbon content. These two ingredients melt at different horizons in the cupola and, as the resulting metal analysis shows that the steel has not become highly carburized before melting, the cast iron produced must be a mixture consisting of a matrix, similar in character to that of the original pig iron, in which crystals or crystal grains of steely iron are distributed without being homogeneously dissolved.

This doubt as to the efficient distribution of the steely crystals in the remelted pig iron matrix should be boldly faced for, although it is true that the metal as a whole is strengthened by the steel additions, the possibility of segregation at undesirable points in the casting structure must be recognized.

The variation in the mechanical test results from castings of this type of metal may be partly traced to the segregation of steely crystals and to the admixture of weak and brittle hyper-eutectic iron in the mass. Although the chemical analysis of the casting may indicate that the structure is hypo-eutectic, it is not so, for the matrix is really hyper-eutectic.

After much experience in the practical study of this problem, I cannot look upon so-called semi-steel as anything but a synthetic mixture, differing entirely from an iron of similar analysis which has been simply remelted from pig irons of approximately the same analysis.

Dilation Characteristics: One of the most useful points raised in the paper is the parallel drawn between the dilation curves of the pig irons and the castings made from the same pig irons.

Figure 13 brings out this point in a most striking manner and, I think, bears out my contention that the characteristics of the casting metal copy those of the original pig iron used, although in the cupola mixtures about 14 per cent of steel scrap was used, together with 36 per cent of gates and sprues and high silicon iron.

It should be noted that the pig irons from Lots 3 and 6 are similar in chemical analysis, the unetched micro-structures in Figs. 3a and 3b both showing the type of matrix containing very finely divided close packed secondary graphite flakes which, I think, are representative of super-cooled conditions.

If the large straight flakes represent the primary graphite deposited during normal cooling, following the super-cooling, the series of unetched micrographs become very instructive, for they would appear to show that the two types of cooling can occur in the same iron.

In Fig. 5 the pig irons in Lots 2, 3 and 6 have similar dilation curves and show the greatest permanent growth. The remaining irons show the same type of loops at the temperature 1400 degrees Fahr. to 1725 degrees Fahr. (760 to 940 degrees Cent.).

Particular attention should be drawn to pig iron Lot 7, which has the highest silicon content in the series and is of eutectic composition. This iron shows the least permanent growth.

It is unfortunate that the complete chemical analysis showing the combined carbon and graphitic carbon contents of the $1\frac{1}{4}$ inch, $\frac{3}{4}$ inch, $\frac{3}{8}$ inch and $\frac{1}{4}$ inch thick portions of the hardness test bars 6c is not given, as the combined carbon content would be an additional index to the Brinell hardness plottings.

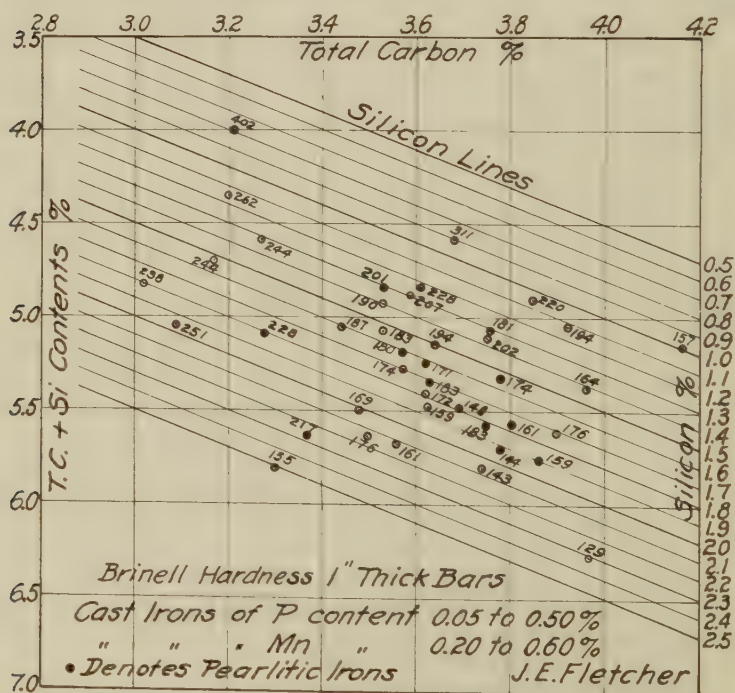


FIG. 1 (J. E. FLETCHER)

Effect of Moisture in the Blast: In a number of cupola tests recently made the effect of moisture has been studied and I have found differences in rate of melting and in the combined carbon content and Brinell hardness directly attributable to this factor.

In a particular foundry where tests were being made over a considerable period the type of cupola mixture used was constant for the production of thin castings of standard form. In wet weather, a number of castings were rejected because of super-hardness and there were a greater number of mis-run castings during the same period.

The effect was the same as occurred when an attempt was made to use an excess of air at a higher pressure in the cupola and it would appear that the oxidation effect when the air contained large percentages of moisture was increased.

The rejected castings through hardness were higher in combined carbon but lower in total carbon than in dry weather.

My experiences would seem to confirm that of the author who suggests that the presence of oxide of iron in the metal may affect fluidity. In the foundry, experiments cited enables one to follow at a glance the relation of any particular fact such as Brinell hardness, combined carbon, chill depth, permanent growth, tensile, transverse rupture stress, and deflection, etc., to the T. C. plus Si, Si, and T. C. values.

I have marked on the diagram (Fig 1 of this very discussion) a number of Brinell hardness figures taken from a series of similar test bars 1 inch thick.

Dry Sand and Green Sand Test Results: The author's proof that the iron of the analysis stated, after remelting in the cupola and casting in dry sand and green sand molds, was higher in combined carbon content and Brinell hardness in the dry sand than in the green sand castings is of considerable importance.

Before accepting this as a proof that all gray cast irons, when cast in dry sand molds are harder than the green sand castings, there should be a wider field of experience, as I have not found this to be universally the case.

My exceptions to the rule may, of course, be accidental and it would be interesting to have the author's explanation.

Experiments in this country on the combustibility of blast furnaces and foundry cokes have been proceeding for some considerable time and as I have found many exceptions to the rule, we thought we had found, that high combustibility must accompany high speed of melting, there is not a little doubt existing that the rule is not yet proven. There is no doubt, however, that the shatter index, together with the combustibility test, together perhaps with a properly conducted rumble test, provide good indexes of the coke quality.

Like our American foundry friends, we are troubled with the variation in mechanical test results in castings of similar chemical analysis.

I have realized for at least twenty years that the character of castings depended upon the character of the pig irons used in the cupola mixture and I congratulate the author in having given further proof of the fact that, if the blast furnace produces iron of a certain physical character, the castings made from a remelt of the same irons will possess similar physical characteristics, though these may sometimes be masked or modified by the presence of other classes of pig irons in the mixture.

I cannot entirely agree with the author's statement that basic or acid slag modified the hardness of pig irons made when the furnace was producing one or other of the slags.

I have found, however, that when the slag was too basic the iron tended to lose silicon and sometimes to considerably increase in total carbon content.

We often find that pig iron cast from a hot furnace makes softer iron than that cast from the same furnace at a lower tapping temperature.

A great deal depends upon the total carbon content of the iron made.

A. L. BOEGEHOLD: In general our experience regarding the relative hardness of cast iron poured in dry and green sand molds of like size and section agrees with Mr. Fletcher's, namely that the iron poured in a dry sand mold will be softer. The reason for the reverse being true in the test bars used in this investigation is due to the difference in surface to volume ratio of the test bars used. The step bars have a much larger area of surface exposed per unit volume of casting than do the slabs which were cast in green sand, as will be seen from the following table:

Casting	Ratio of Surface to Volume
1 $\frac{1}{4}$ " slab in green sand.....	2.07
1 $\frac{1}{4}$ " part of step bar.....	3.88
$\frac{3}{4}$ " slab in green sand.....	3.14
$\frac{3}{4}$ " part of step bar.....	4.45
$\frac{3}{8}$ " slab in green sand.....	5.9
$\frac{3}{8}$ " part of step bar.....	9.9

The extra cooling surface of the step bar castings is responsible for the greater cooling rate and therefor greater hardness than the green sand cast slabs. With equal surface to volume ratios for both castings, the dry sand castings would be softer.

WRITTEN DISCUSSION—SUBMITTED BY R. S. MACPHERRAN*

This paper, to me, contains more of interest than any I have read for years. It is going back to the basic production of pig iron, and researches of this type should have the heartiest support and cooperation of all foundrymen.

Mr. Boegehold shows, among other things, the variable conditions under which pig iron is made, together with the probable result that those variations will be passed along to the pig iron produced. Many of us have believed for years, that the blast furnace gave an initial trend

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to pig iron which persisted through the cupola operation, but we have never been able to prove it. The tests shown here seem to confirm this belief.

In the making of chilled iron castings, we have often come across cars of pig iron which seemed to give greater than or less than the chill to be expected from the analysis. On page 126 the author refers to this fact and offers in explanation the various degrees of humidity in the blast at the furnace.

The author's experiments, unfortunately, were all conducted on high silicon pig iron showing a light chill. I sincerely hope the car wheel makers and others interested in chilled iron, as such, will see their way clear to duplicate these tests but will use low silicon irons showing, naturally, a deeper chill.

The author, on page 129, refers to the liquid shrinkage as affected by the rate of reduction of the ore in the furnace. He suggests that while deoxidized iron may pipe deeply where such shrinkage is expected, the oxidized irons may have this property scattered around the casting and, therefore, less under control by the use of risers.

The coke test he describes seems to be a very interesting as well as successful test and illustrates the importance of the variation in the coke used on the properties of resulting pig iron.

WRITTEN DISCUSSION—SUBMITTED BY J. W. BOLTON*

In this excellent paper by Mr. Boegehold, we have the first comprehensive attempt to establish quantitative relationships between pig iron of similar analysis made under various blast furnace conditions and the quality of gray iron cast therefrom. As a pioneer effort, it will serve as an inspiration to others, and a foundation upon which more work will be built.

On page 130 the author has made some comments which, by inference, are far reaching. The absolute cohesion within metal crystals is very high, yet a very small percentage of this great theoretical strength is preserved in commercial metals. In metals of more homogenous type structure than gray iron, this weakness is, to a large degree, attributable to looseness between the grains of the metal. Such a condition is manifest as an incipient shrinkage or to microscopic fissures. In a paper read last February (*Incipient Shrinkage in Non-Ferrous Alloys*, American Institute Metals), S. A. Weigand and the writer showed that by combating such internal incipient shrinkage, the tensile strength of a certain bronze was increased some 20 per cent, with improved machining properties. In recent work, the writer's staff has slightly increased the commercial cutting rate 20 to 30 per cent, based upon theories developed in presentation of a paper before this Association at its 1928 convention.

It is true that as fissures graphite flakes in gray iron play an extremely important part, to the writer's mind usually the most important

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part, in disturbing the continuity of the matrix. Yet, as Mr. Boegehold asserts, different pig irons possess different shrinkage characteristics; and he offers some tentative explanations. These are not reflected in the specific gravity figures. We, too, have done some work (unpublished data) trying to correlate specific gravity with tensility. While there is a distinct general relationship, it is more qualitative than quantitative. Furthermore (as published in *Foundry*, August 15, 1924, p. 631), we check Mr. Boegehold's findings where he shows that iron poured at 2275 degrees Fahr. is too cold to pipe, hence shows little external shrinkage. However, such metal shows pronounced incipient shrinkage and is of low tensility.

The thing we are getting around to is the well known foundry adage that iron melted hot and poured reasonably hot is dense and strong. This is due to the fact that it feeds better, as well as to graphite nuclear absorption and surfusion phenomena observed by continental investigators. To these things Mr. Boegehold adds data which show the inherence of certain characteristics possessed by the pig irons. In other words, with more ideal blast furnace conditions and correct foundry practice, some day it will become possible to produce very strong irons of high machinability, perhaps of quite different analysis than those made today. Internal soundness of gray iron is a fruitful field for investigators.

There is only one criticism of the paper—lack of tabulated data which others can study and perhaps draw further conclusions. The micrographs can be easily correlated with the analysis (pp. 105-107) as moderately and highly hypereutectic (according to the classification in the writer's 1927 A. F. A. paper), except micrograph 4, which appears more moderately hypereutectic than is indicated by analysis. Lots 1 and 7 are very characteristic and the C + 0.3 Si shows 4.31 against 4.62.

A. L. BOEGEHOLD: Answering Mr. Bolton's plea for more data, the only reason we did not include all of the data that we had in this investigation was because of its extent. We probably would have had a paper about four times as long as this present paper if we had put it all in, but if anybody wants to go into that data, I will be glad to let them have copies of it.

ORAL DISCUSSION

R. H. WATSON: There is one gentleman here whom I believe had the honor of hearing Sir Lothian Bell's paper before the British Institute. Most all the metallurgists from that day have taken this work as a foundation, and practically every book on blast furnace work quotes from this eminent author, who brought a new era in blast furnace knowledge. It is, therefore, with a great deal of pleasure that I have read this paper of Mr. Boegehold's to find he has cut away entirely from this foundation and sailed into his own with relation to the quality of pig iron and cast iron as affected by blast furnace practice.

It was my very good fortune quite a number of years ago to be employed at the Isabella Furnaces and the Lucey Furnaces where I was able to obtain first hand information on the effect of the dry blast upon blast

furnace operation and the resulting pig iron. At that time the chemist had to break and drill his own samples. I found one very salient fact; that the sample taken from the furnace on dry blast with the same silicon content was very hard to break but very easy to drill.

We did not have enough dry blast to operate both furnaces and worked alternately with it on one or the other of the furnaces. Our specifications called for a silicon of 1.60 and this iron was used in the Bessemer converters. When we switched from the ordinary air to the dry blast we found by experience that we could add 25 per cent more weight to the charge on the same amount of coke and still secure an average 1.60 silicon. Unfortunately, the Galey dry blast was sold entirely as a device for saving coke. It was indiscriminately placed in the north where nature gave a dry blast for nine months out of the year instead of being placed in those localities where very high humidity occurred. Under these conditions the Galey dry blast was not a financial success and the discontinuance of its use prevented metallurgists from discovering until very recent years the effect of moisture upon pig iron.

I was very much interested in this moisture test and on being sent as assistant superintendent to the Ohio Works, of the Carnegie Steel Company, I carried out this experiment. I secured a sling psychrometer and four times a day took the moisture content of the air at the intake of the blast furnace blowing engine. For example, when we ran over four grains of moisture in the air, I distributed extra coke throughout the charge and when the moisture fell below 3 grains I cut coke from the regular charge and by operating on these lines, I secured a uniformly hot iron of even and uniform silicon content.

In connection with this and also taking up a part of Mr. Boegehold's paper on coke, let me say that we devised coke a rumble test by simply drilling holes with inch centers, inch in diameter in the ordinary oil drum. Into this we put 100 pounds of coke and turned it for one hour at the rate of 20 revolutions a minute. Where the resulting breeze was more than 4 per cent we added coke to the charge to make up for the lack of structure. By using the moisture and breakage test we were able to operate our blast furnaces uniformly and to prevent slips, thus preventing the inclusion of unreduced oxides in our pig iron.

In the manufacture of foundry iron, we have found that the moisture in the air, the character of the coke, and the chemical analysis of the slag enter largely into the manufacture of good castings.

For example, a pig iron made in the blast furnace where the analysis of the slag is as follows: silica 35 per cent, alumina 17 per cent, with a high stove temperature will produce a stronger and better grade of castings than a pig made in a furnace where the reduction takes place, of necessity, higher due to a slag less viscous in character.

It seems to me that the manufacture of gray iron castings begins in the blast furnace because the casting temperature of the pig iron practically regulates the character of the iron and the castings made from this

iron. It has been my experience that the character of the pig iron is not changed during its passage through the cupola.

I was at a certain foundry a few days ago where they were making a centrifugal casting. They were securing soft spots in the bell of this casting. An examination of the pig iron showed scurf about an inch thick on some of the pigs and none of the pigs were without some of it. In order to determine whether or not this was the cause we picked out enough pigs with the least amount of scurf to run a heat and on this heat this trouble entirely disappeared. We ran the next day on the pig iron with large amount of scurf and the trouble immediately returned.

It, therefore, seems very necessary to me that our blast furnaces should be operated in the most uniform manner with coke of a known burning rate and a known structure so that the travel of the burden through the furnace may be made rapidly and without slipping.

The combustion test which Mr. Boegehold has devised takes the guess work out of the coke and allows us to carry a heavy burden on the furnaces, giving a low coke ratio which a few years ago was unthought of. The best ratio on foundry furnaces today is 2.41 pounds of ore to 1 pound of coke. I know one furnace where this ratio is regularly obtained and the silicons on this ratio are regularly over 3 per cent.

It would seem a necessity to me that the operation of a cupola on coke of a known combustibility with a measured amount of air and with penetration of the blast would reflect at once the character of the pig iron used in the charge. It would also seem to me that the temperature at which the pig iron was made and the temperature at which it was cast from the cupola would be affected on every occasion by the amount of moisture contained in the air.

I personally wish to thank Mr. Boegehold for the study he has given to this important phase of foundry work.

R. MOLDENKE: I was very glad to see this question of moisture brought out, because I feel that we are approaching the time when we are going to more and more take the moisture out of the air for our cupola work. This is because all the points brought out about deep chills, etc., are all due, in my opinion, to the fact that where there is water present in the blast for the cupola or furnace, you will have oxidation of the iron.

The point about easier machining of cast iron when dry air is used is important. I have seen cases illustrating this; hard iron with high silicon results where they should not have such results. The problem is going to come to putting in ice machines and removing the moisture in the blast before it goes to the cupola. If to that can be added pre-heating the blast, so much the better.

There was no mention of impact tests. Were there any?

A. L. BOEGEHOLD: There were no tests of that kind.

R. MOLDENKE: I think that an impact test is an important thing. The whole trend of the paper points to that which I think we are going

to come to, namely to find some method of testing pig iron. I am working on that problem myself, and I'd like to see included in your tests some information on resistance to impact.

R. H. SWEETSER: This is the day that we blast furnace men have been looking for for a long time, and I want to congratulate Mr. Boegehold and the General Motors Corporation for the wonderful job they have done. This paper has shown the foundrymen that pig iron is complicated. I am not going to admit that it is "diabolical," as Mr. Allen has just said, but it means that we have to go at this in a scientific way, and Dr. Gillett has brought out the point that there is a very thin margin between the really pure scientific research and the commercial investigation.

There are two things I want to mention. One is about this moisture in the blast. Don't forget that when the moisture in the air for a blast furnace goes into the hearth of a furnace, it is heated at a temperature of 1200 to 1400 degrees, and that hydrogen going through the blast furnace comes out in the gas at the top of the furnace, as hydrogen.

There has been no proof yet that that hydrogen has any chemical effect inside the blast furnace. The blast furnace man has to add a little more coke to compensate for extra moisture in the blast. I will throw that out for the cupola men when they are taking their humid air and putting through their cupola without any preheat. Moisture in the blast for both cupolas and blast furnaces should be more carefully studied.

The other point that is brought out by the paper but not in the discussion is this: foundrymen want regularity in their pig iron; blast furnace men have been trying to get regularity in all of their operations. The foundrymen are to blame for one irregularity that they can correct. That is the difference in the variations of very small percentages of manganese and of phosphorus for the same silicon sulphur contents of their pig iron. Some man will want his phosphorus under 0.14 per cent; the next man will insist that it is not under 0.15 nor over 0.18 per cent; another man wants it under 0.20 per cent.

Now remember that the mixture going into the furnace must be changed to make those little variations in manganese and phosphorus. The variations in silicon can be taken care of by the blast temperature and the amount of coke, without changing the ore mixture.

One other point—this paper speaks about the silicon being taken out of the iron as it passed through the zone of combustion. The facts are that there is very little silicon in iron sponge before it reaches the combustion zone. That question will have to be studied further.

Another thing, the thought expressed by many that there is oxidation of iron as it comes down through the combustion zone, is, to my mind and the opinion of most blast furnace men, all wrong. What is really the case must be proved by research.

A. L. BOEGEHOLD: Replying to Mr. Sweetser I wish to say that the fact that hydrogen comes out at the top of the blast furnace is not proof

that it has no influence on the iron in passing up through the stack, any more than the fact that the presence of CO in the top gases proves that CO has no influence on the iron. We know that the CO formed in front of the tuyeres reacts many times before it finally appears in the top gases. There is no reason why hydrogen shouldn't also. It probably does. Hydrogen may be merely an agent for introducing some other element into the iron by first forming a compound with that element and then dissociating to create a nascent condition of that element. Nitrogen in air is inert but when combined with hydrogen, ammonia is formed, which will break down, giving atomic nitrogen which we know combines with iron to form iron nitrides.

The addition of a little coke to supply extra heat to make up for that used in dissociating water in the blast is a satisfactory means for correcting a poor thermal condition but it does not remove the hydrogen. The addition of the extra coke then does not prevent the chemical effects that might occur when hydrogen is present.

Regarding the presence of silicon in the sponge iron, I presume that can be definitely shown by taking samples from a furnace that has ceased operating. But the absence of silicon in the sponge iron does not prove that silicon is not reduced from the slag at a point well up in the bosh. Alfred Stansfield on page 266 of his book "The Electric Furnace," gives data showing that silica is reduced in the presence of carbon at a temperature of 2660 degrees Fahrenheit but that when iron is also present silica is reduced to form ferro-silicon at a temperature of 2192 degrees Fahrenheit. This happens to coincide with the melting point of 20 per cent silicon ferro-silicon. The presence of lime may make necessary a somewhat higher temperature. The temperatures a short distance above the zone of combustion are probably sufficient to reduce silicon when lime and iron are present. This reaction would probably proceed rapidly around 3000 degrees Fahrenheit, which Camp gives as the temperature halfway up the bosh where the slag has formed and is fairly fluid. At this temperature there is plenty of molten iron present to absorb all silicon the instant it is reduced. In this way it seems perfectly plausible to have liquid iron containing considerable silicon formed fairly well above the zone of combustion.

J. T. MACKENZIE: I think that it would be well to request the Association to publish the detailed data of Mr. Boegehold's test. It certainly is impossible to check the data. For instance, I should like to see the silicons of one content plotted against the moisture for chill and the moisture content of the same rate of driving plotted.

I'd also criticize the fact that while these tests were run in a production foundry, there are none of the foundry loss records given and no records of production machining. It seems to me that the production machining for a three weeks' period would be more reliable tests on machinability than the machinability tests. If they were not, the knowledge of this correlation would be very valuable to have, that is, that the machinability test did actually check out in the foundry.

Also the matter of shrinkage. Mr. Boegehold reports the volume of the pipe but as Mr. Bolton brought up, that would not include any subcutaneous shrinkage or any microscopic shrinkage.

We also have no way of checking up the value of the tests themselves. We have tried the Cury tests for fluidity at the Bureau of Standards and found it must be very, very carefully controlled to give tests of scientific value. I have no doubt in three weeks' time the average of all those tests would be reliable for the particular pig iron tested, but at the same time, it would be interesting to see whether one pig iron varied four inches in the test and another one varied six, or whether all of them varied six inches, etc.

I'd also like to bring out the point that at infinity temperatures, the reaction velocity of all cokes would be the same. Therefore, the higher the temperature of the test, the less difference you could expect to find in the reactivity of the cokes.

Now, a test at 800 degrees might show considerable difference in two cokes, whereas in the blast furnace at 1500 degrees Cent. it would fade out.

I also heard the word "absolutely" used in this discussion. I'd like to remind the meeting that Einstein has eliminated that word from our technical vocabulary.

E. J. LOWRY: Two of the men from the Bureau of Standards, S. P. Kinney and C. C. Furness, on February 20th, before the A. I. M. E. published a paper showing the difference in reduction of velocity of gases. They examined blast furnaces and took planes at 6 feet, 13 feet, 24 feet seven inches, and 47 feet below the stock line. They measured the velocity of the gas. They found at center the velocity was as high as 400 feet per second, whereas at the side wall it was 80 feet per second. Therefore, the flow of gases through the furnace was not uniform. They showed in three comparative furnaces at the 24 feet 7 inch plane 4.6 per cent ore was reduced in a South Chicago furnace, whereas in an Alabama furnace 61.4 per cent was reduced, whereas in a Utah furnace 76.4 per cent ore was reduced. It was brought out in this paper that in the latter furnace there was uniformity in the sizing of the ore, and therefore they bring in a condition which was not taken into consideration in this paper by Mr. Boegehold.

A. L. BOEGEHOLD: It is quite impossible for me at this time to cover all the points that have been brought up in the discussion so far. Written replies will be sent in to be published in the proceedings. One or two points I might touch on—one is the coke test which Mr. MacKenzie stated might not mean much at the higher temperatures. That may be true, but we know that in using that coke test on foundry cokes, we find that the behavior in the cupola falls in general along the lines of the coke test.

I might give one instance of fast burning coke used in a cupola melting malleable iron. With a fast burning coke, you can melt the iron

with much less coke than with a slow burning coke, and we have cut down the amount of coke considerably, simply by using this combustibility test to inspect our coke. Of course, the proof of the pudding is in the eating, so it is that the value of a test depends upon the advantages that can be derived from its use in every-day practice.

As to the rejections on the castings that we made, a very large proportion of those rejections were due to things that we could correct by molding. At one time we had a number of rejections for dirty iron, which we were able to eliminate by changing the gating. At times when we poured iron too cold we got a shrink between the juncture of the web and the rim. We eliminated that by pigging the metal when it became too cold.

The chemical specifications and hardness tests for the fly wheels were so wide that the hardness analysis could vary considerably without having the castings rejected. We felt the more accurately controlled tests on the test bars were more indicative of the physical qualities of the iron than the study of those properties on the castings. We shipped the castings away and they were all mixed up with 4,000 other fly wheels every day and it was quite impossible to keep check on the machining of those.

Hight Test Cast Iron—Discussion

Papers presented at the session on High Test Cast Iron were discussed as a group. These papers were divided into two classes: (1) those on European Developments, by R. P. Lemoine (page 259) and E. E. Marbaker (page 405), and (2) those on American Developments, by F. B. Coyle (page 469), R. S. MacPherran (page 495), and O. Smalley (page 485).

E. E. MARBAKER: The paper I presented is a compilation of a large number of descriptions of processes worked out in Europe. If any of you are interested in reading a much more complete paper of this kind, I would recommend the article by Jungbluth, which appears in *Krupp's Monatshafte* for April, 1929. In my paper I have followed his method of attack in a general way.

Since preparing this paper, I have discovered another method of producing high test iron, which was described in the literature a few months ago. This is based on the use of a new furnace called Brackelsburg furnace, which is in fact a rotating cylinder lined down with ordinary refractory lining. It looks something like a cement kiln. It is charged at one end and a powdered coal flame is admitted at the same end. The tap-hole is located at the center of the cylinder. When the charge is placed in the furnace, it is first rocked back and forth until the iron is molten; then the furnace is rotated completely and a protective slag is alleged to be formed, which prevents any absorption of sulphur or combustion gases. The coal flame goes straight through the furnace and is not directed down on the bath. Mr. Lemoine said in his paper that if you want to make a high sulphur iron, all you have to do is to direct the powdered coal flame into the bath. In this furnace the flame does not directly heat the iron at all, it heats the lining, and as the furnace revolves, the iron comes in contact with the hot lining and is melted by virtue of heat supplied by radiation, and this protecting slag covering is responsible for many of the good properties claimed for the iron. It is alleged that you can do all sorts of things with this furnace by regulating the temperature and the charge, and the idea seems to be to obtain the eutectic composition. It is claimed that very thin sections can be poured, and that the iron is of the high-test variety.

H. P. KREULEN: For several months we have made a low total carbon iron with a fairly high breaking strength. The standard arbitration bar would break around 5,000 pounds; some broke as high as 5,500 pounds, and around 44,000 pounds tensile. This iron was poured into automotive castings, cylinders, cylinder heads, manifolds, gear covers, etc.

The cylinders would give Brinell readings from 200 to 220 in the bore. This iron showed gray in sections as thin as $3/32$ of an inch, but the cylinders were too tough to machine for production work. That is the reason we are not making this low carbon high test iron at the present time. We eliminated shrinkage and porosity with this low carbon iron. The mixture I used was 20 per cent pig iron, 10 per cent lump ferro-silicon (in the cupola), 25 per cent steel, and 45 per cent returns and scrap.

The total carbon of this mixture ran from 3.00 to 3.10 per cent. We did not make any special arrangement regarding melting control. Several of my foundrymen friends who were in our plant during the time this iron was being melted, practically all doubted our analysis and several checks in various laboratories were made, checking with our chemist. The silicon ran from 2.60 to 2.90, manganese 0.60 to 0.65, phosphorus, 0.20 and under, sulphur, below 0.10, nickel, around 0.15, and chrome around 0.25. With this low carbon mixture the silicon variations are not as dangerous as they are in the low range, say 2.00 to 2.30 per cent carbon. As stated before, we have had no chilled edges, although we maintained a very high Brinell strength.

The mixture I used as stated before, was for truck, tractor and bus cylinders and castings that go with that type of motor. For heavy cylinders such as Diesel engines, we would have used a different mixture. We would use from 40 per cent to 50 per cent steel and reduce the silicon to around 2.00 to 2.30 per cent. The test bar of this mixture would break much higher than for the other mixture. We now are running the total carbon from about 3.25 to 3.40 per cent and silicon 2.30 to 2.60 per cent.

R. F. HARRINGTON: I understand Mr. MacPherran to say that in his high test iron they noticed an over all increase in contraction and only a slight increase in liquid shrinkage, but did you use large risers?

R. S. MACPHERRAN: We slightly increased the size of the risers and gates. We have seen no signs of any increased internal shrinkage.

R. F. HARRINGTON: Have you run enough castings without the large risers to be satisfied that that condition exists?

R. S. MACPHERRAN: I would not say that it would be necessary to put extra risers on. We put them on as a matter of precaution. We are using a new material in a casting weighing six or seven tons, and we do not want to take chances.

I was glad to note Prof. Lemoines' comments on the recent patents taken out in this country on melting high percentages of steel in a cupola. This last week I found in our records that over fifteen years ago we were using a mixture of between 60 and 75 per cent steel. We have used this mixture ever since. The patent is not worth anything.

J. A. AITKEN: Mr. Coyle said that he added both carbon and silicon to the ladle. How does he maintain his temperature with these additions, particularly when he tries to obtain a nickel content of 2 per cent and still be able to make light castings?

F. B. COYLE: In my own foundry I have made a great many heats, casting material in $\frac{1}{8}$ inch sections; the metal coming from the cupola is extremely hot. I have recorded temperatures (with the proper correction as indicated in the paper by Roeser and Wensel*) as high as 2900 degrees Fahr. with the minimum tapping temperature 2700 degrees Fahr. I have added as much as 2.25 per cent silicon, and 3 per cent of nickel in the spout and have poured castings $\frac{1}{8}$ inch thick.

J. A. AITKEN: Without preheating nickel?

F. B. COYLE: By all means ladles should be preheated, but the alloy was not preheated.

J. A. AITKEN: How much coke between charges?

F. B. COYLE: About seven to one in between.

T. F. KILEY: Mr. MacPherran made a statement that in pouring this high test cast iron, he had to go to a better quality of sand. I would like to ask him what he means by a better quality of sand.

R. S. MACPHERRAN: I should have said a sharper sand.

T. F. KILEY: More refractory?

R. S. MACPHERRAN: Yes, because the iron seemed to burn in.

T. F. KILEY: This was green sand?

R. S. MACPHERRAN: No, almost all that is dry sand work; it is better to use dry sand and blacken your gates, because this metal is poured hotter than the ordinary, and the lower carbon contents of the iron seem to attack the sand. We would get more gas if we poured in green sand. This iron has a very short freezing range. An ordinary iron cools off more gradually and the ferrite first freezes out. The mixture has a freezing range of several hundred degrees. This high test iron sets very quickly. It should be poured fairly hot. We have made some castings in green sand, but the dry sand or skin dry molds are to be preferred.

R. MOLDENKE: I want to say in regard to the first paper, in which the getting of the same fracture for thick and thin surfaces of a casting is discussed, that I myself saw, on the other side of the water, pieces from the casting; one, a section eight inches thick, and another about an inch thick, run as a rib, both with absolutely the same fracture and no sign of shrinkage inside or outside.

I want to say further, in regard to Dr. Marbaker's paper, that I hope some day he may get across the water and see some of the things they claim are being done over there. He will find that many are abandoned by this time. The jolting of the forehearth accomplishes very little. You will get the same result if you let it remain stationary. I saw the operation in Berlin, slag being piled on the iron in a lump, and it looked as if they would probably shake the slag into the iron rather than out of it. I met Corsali, who had that peculiar ferro-alloy feeding arrangement in the cupola, but found that his method was abandoned. In one of the new furnaces for high test cast iron, I saw one heat that was a failure and

*Temperature measurements of molten cast iron, transactions A. F. A. Vol. 36 (1928) pp. 191 to 212.

another that was magnificent. The point is that a lot of the new announcements coming out at present want to be discounted a good deal, and by and by we will get the grains of truth out of a lot of the accompanying chaff.

As to patents—I do not think patents on any one of the things we have heard about here will hold water, because they are all old stories. They can patent certain combinations; for instance, take pearlitic cast irons—if you get a certain silicon content in connection with a certain mold temperature and get a certain result, that combination can doubtless be patented, but if you vary the silicon content or vary the temperature you will avoid the patent altogether.

J. T. MACKENZIE: I would like to correct the impression that might get out, that just because a mixture is a eutectic mixture it will not shrink. A eutectic mix will not show shrinkage if the mold is completely filled at the freezing point, but at any temperature at which you pour, you have to watch out for shrinkage, whether you have a eutectic or any other alloy.

I would also like to comment on Mr. Coyle's statement that definite elastic limits showed in the order of 10,000 pounds. I can hardly believe that. All the curves I have ever seen on cast iron vary continually, and while they show quite decided deflections, there is no such break as you have at the elastic limits in steel.

I would also question very much Mr. Smalley's results on the modulus of elasticity, where he shows that the modulus was actually increased from 28,600,000 to 29,200,000 in tension, while the deflection increased in the transverse test three times. Of course, the modulus of elasticity of cast iron depends on the load and is lower as the load increases. Possibly Mr. Smalley was including some plastic set also in the bar that showed higher deflection.

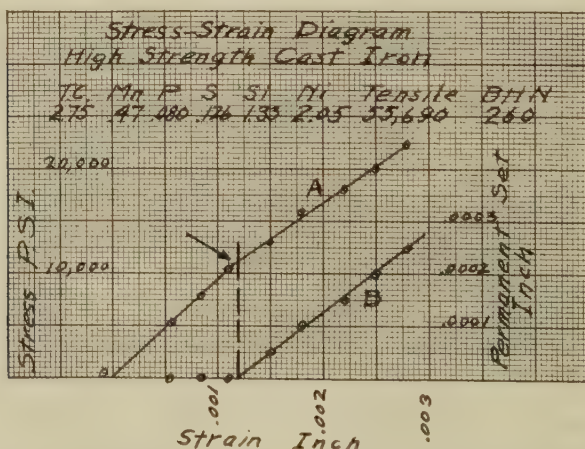


FIG. 1—STRESS-STRAIN DIAGRAM—F. B. COYLE.

Along this line of high-test cast iron, I think that a great many foundrymen might be under the impression that they need high strength iron when what they need is a sound casting of the metal that they are making.

F. B. COYLE: The method for determining elastic limit was as follows. Test pieces were standard 0.505 inch diameter threaded end specimens. The initial load was 1,000 pounds and subsequent loads 500 pounds. The specimen was loaded and the load maintained about five minutes and then entirely released. Any permanent set was recorded. A Berry Strain gage with a dial marked in divisions of .00005 inch was used. The divisions were wide enough to read this dimension accurately. The stress-strain relation obtained in this manner is shown in graph A in the accompanying Fig. 1. Graph B shows the relation of permanent set for each loading. The graph was projected to the zero axis. A perpendicular line was erected at this point and the point at which it intercepted graph A was taken as the point of zero permanent set and designated the elastic limit.

O. SMALLEY: The modulus of elasticity figures that I quoted were determined at the Stevens Institute and the work was done under very careful conditions. Anybody who has determined modulus knows that it is not a very specific property, and that it does not vary directly as the deflections of the transverse test piece under load, when both the elastic and plastic properties of the materials compared differ appreciably. The results found on test are quite as expected when one considers the higher elastic limit, higher plastic set of the heat treated sample. The deflection figures represent the actual deflections of the machine under load, not after the load was taken off.

E. F. CONE: A short time ago I realized that there was a great deal of alloy cast iron made in this country and we wrote to 3818 iron foundries. We have had responses, up to the time this article was written, from 49.5 per cent. Since that time a good many other replies have come in, and they have responded to the extent of at least 51 or 52 per cent, which I think is remarkable.

There are one or two points that came out in that survey that have not been mentioned here. One is that considerable Norwegian pig iron containing vanadium is being used in this country for making an alloy cast iron, or a high test iron. The vanadium in the pig iron runs from 0.50 to 0.60 per cent. In the casting, the vanadium runs from 0.05 to 0.10 per cent. Some of it is used for iron dies and some for other purposes.

Another point brought out in the survey which has not been mentioned here is the use of molybdenum; that is being used extensively, more extensively than is generally known, at least, in iron rolls, for rolling mills, and also in a good many other lines of castings, like cylinder blocks, etc. It has been introduced into the iron by three different compounds of molybdenum. Another thing which I have heard recently and which is in line with this discussion is that one or two foundries are using rocking electric furnaces, and they claim for it, that one not only gets the high temperature, but also the jolting action.

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